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A Compact DGS Low Pass Filter using Artificial Neural Network

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***Abstract*—This paper presents the use of artificial neural network for the estimation of cut-off frequency in a design of Low Pass filter (LPF) by varying the lengths in defected ground structure (DGS). Levenberg-Marquardt training algorithms of MLPFFBP-ANN (Multilayer Perceptron feed forward back propagation Artificial Neural Network) has been used to implement the neural network model. Simulated values for training and testing the neural network are obtained by analysing the DGS-LPF structure by the use of CST Microwave Studio Software. The result obtained from ANN tool are compared with the simulation findings and found quite satisfactory and also it is concluded that by increasing the lengths of defected ground structure (DGS) there is a decrease in cut off frequency and transition width of the proposed filter.**

Keywords*— *Defected ground structure (DGS), Low Pass Filter (LPF), Artificial neural network (ANN), Computer Simulation Technology (CST).

I. INTRODUCTION

In microwave system frequency response at a certain point is control by a two port network device known as microwave filter. These filters transmit the frequency within pass band and provide attenuation in the stop band of the filter.

The low pass microwave filter is using defected ground structure as it is simple and it is easy to design DGS pattern. The resultant circuit size becomes relatively small by the use of defected ground structure. For these reasons, the DGS has been extensively applied to design microwave circuits such as filters, power dividers, couplers, amplifiers, oscillators, and so on[1,2], [11-13].Different defected ground structures are mention in [14] among them the simplest structure is dumbbell shaped defected ground structure[1] and it is used here to design a microwave low pass filter.

Highly interconnected processing elements are combined together to make a computing system, which processes information by their dynamic state response to external inputs is called **Artificial Neural Networks (ANNs)**.

In ANN tool for training and testing purpose various type of neural network architecture are used. We use **feed forward back propagation** [10] neural network for training purpose as it is quite popular network.

In this paper, an attempt has been made to exploit the capability of artificial neural networks to calculate the cut off frequency of DGS-LPF network and the paper presents a simple and novel design for achieving the cut off frequency of dumbbell shaped DGS low pass filter for specified range, using MLPFFBP with five different variants of back propagation training algorithms as in [15].

II. DESIGNING OF DGS LPF

It can be shown in the figure: 1 that broader line is fixed at 3.5mm, while the width of the 50-Ohm micro strip line is only 1.7mm. This figure shows dumbbell shape DGS Structure with all its parameter keeping constant apart from L1 and L2 as they are varied and the change in cut-off frequency (f_c) is observed.

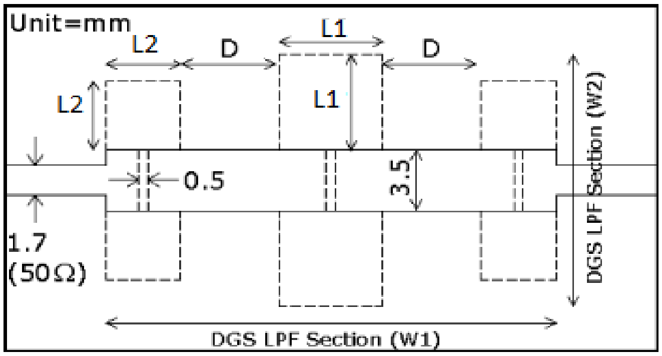


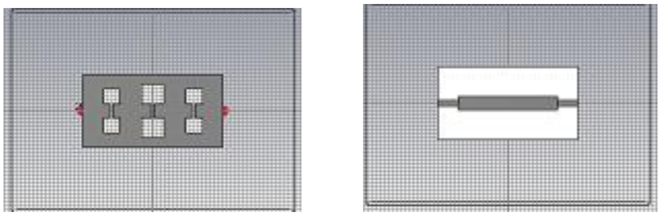
Figure 1: Layout of the proposed for DGS LPF with L1 and L2 are varied and cut-off frequency f_c is been observed

The equivalent L and C depend on the dimensions of the defected area when the size of connecting slot is fixed to be 0.5 mm × 3.5 mm. The equivalent L, is proportional to the dimension of the defected area directly while the equivalent C is nearly constant.

In the figure: 1, separation between the two dumbbell structures is represented by D with DGS LPF Section W1 is fixed at 23.95mm and W2 just keeps on changing with respect to L1 as seen in figure: 1. The length L1 and L2 are varied and the changes are observed in output cut-off frequency fc . The values range of structure sizes L1, L2 is $4.25 \leq L1 \leq 6.25$mm , $3\text{mm} \leq L2 \leq 5$mm .

III. DESIGN IN CST STUDIO

The dumbbell shape DGS-LPF structure is design on rectangular plate having width (W=19) mm and length (L =33.95)mm. The dielectric substrate FR4 (Lossy) is used with dielectric constant (ε_r) = 4.3, and substrate thickness (h) = 1.6mm on a ground plane.



(i) (ii)

Figure 2: (i) Bottom view of DGS LPF structure. (ii) top view of DGS LPF structure

Now by changing L1 and L2 simultaneously according with the range specified it is found that by the increase in lengths, L1 and L2, of DGS-LPF structure there is a gradual decrease in the cut off frequency (f_c) and reduction in transition width. So by simulating each structure by varying its L1 and L2 we observe that the range of cut off frequency f_c, is 3.4322 GHz $\geq f_c \geq$ 2.6886 GHz .

Table 1: Shows the resultant cut-off frequencies obtain after simulating DGS LPF design by using CST by varing L1 and L2.

S.No.	L1(mm)	L2(mm)	f_c (GHz)
1.	4.30	3.05	3.4036
2.	4.50	3.25	3.3369
3.	4.70	3.45	3.2415
4.	4.90	3.65	3.1653
5.	5.10	3.85	3.0890
6.	5.30	4.05	3.0222
7.	5.50	4.25	2.9460
8.	5.70	4.45	2.8697
9.	5.90	4.65	2.7934
10.	6.10	4.85	2.7267

In CST we design a DGS LPF structure as explained in Figure: 1 , and gradually increase the lengths of dumbbell shape defected ground structure as shown in Table 1 and simulate each structure and observe a graph of S-parameters and obtain the cut off frequency(f_c) in each case.

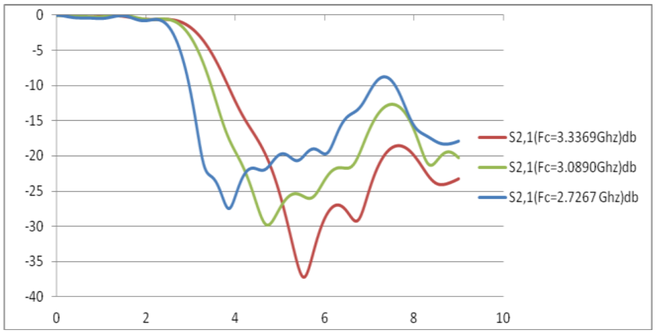


Figure 3: Shows the graph of S_{21} when L1 and L2 are varied.

The graph in figure 3 shows the changes which occur in S_{21} and transition width of low pass filter. In figure 3 it can be seen clearly that the cut-off frequency and transition width of low pass filter decreases gradually by increasing the lengths L1 and L2.

IV. NETWORK ARCHITECTURE FOR ANALYSIS OF DGS LPF

Artificial neural networks are computational models inspired by central nervous system (in particular the brain) that are capable of pattern recognition and machine learning. Neural Network are usually presented as systems of interconnected "neurons" that can compute values from inputs by feeding information through the network.

The artificial neural network model has been developed for defected ground structure of low pass filter as shown in Figure 4. The feed forward network has been utilized to analyze the cutoff frequency fc (GHz) of the filter for the given value of length of the L1 (mm) and L2 (mm).

For the present work two layer perceptron feed forward back propagation neural network (MLPFFBP) [13, 14] is used with Levenberg-Marquardt training algorithms as shown in Figure 4. Desired response of input and output data is required to train these supervised networks, with two hidden layers they can approximate virtually any input output map. There are 10 neurons in the first hidden layer. The weights of the networks are usually computed by training the network using the back propagation algorithm

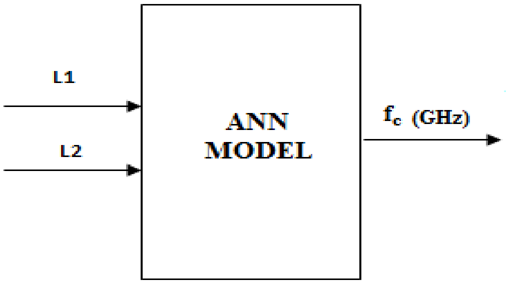


Figure 4: Analysis ANN Model

In order to evaluate the performance of proposed MLPFFBP-ANN based models for the design of DGS filter , simulation results are obtained using CST studio Software and generated 31 input-output training patterns and 10 inputs-output test patterns to validate the model. The network has been trained for a specified range having length is in the range of 4.25mm ≤ L1 ≤ 6.25 mm and width is in the range of 3mm ≤ W ≤ 5mm.

V. TRAINING AND TESTING THROUGH NEURAL NETWORK

Feed forward Back propagation Neural Network is used for training of DGS low pass filter as this is very popular neural network architecture, because it can be applied to many different tasks and the training functions which we use to analyze this network are trainlm, traincgp, traincgf, traincgb and trainscg. Trainlm is a most accurate network training function that updates weight and bias values according to Levenberg-Marquardt optimization.

After training the network from input and its corresponding output data and thereafter testing it with the sample data we obtain the desire output from ANN. Results obtain from CST and ANN is shown in Table 3 and error which occur is shown in next column followed by MSE (Mean Square Error). And as we can see from the table 3 the result obtains from both the tool are approximately equal.

Table 3: The table shows the comparison between the results obtain from CST Studio and ANN for the test patterns

S.No.	**F_c(GHz) CST**	**F_c(GHz) ANN**	**ERROR**	**MSE1**
1.	3.4036	3.4129	-.0093	8.6490e-005
2.	3.3369	3.3272	.0097	9.4090e-005
3.	3.2415	3.2436	-.0021	4.4100e-006
4.	3.1653	3.1740	-.0087	7.5690e-005
5.	3.0890	3.0827	.0063	3.9690e-005
6.	3.0222	3.0150	.0072	5.1840e-005
7.	2.9460	2.9487	-.0027	7.2900e-006
8.	2.8697	2.8678	.0019	3.6100e-006
9.	2.7934	2.7962	-.0028	7.8400e-006
10.	2.7267	2.7226	.0041	1.6810e-005

Table 2: Comparison of different variants of Back Propagation Training Algorithms for the Analysis of DGS-LPF.

S.No.	MSE 1 (CST)	MSE2 (polak-Ribiere Restarts)	MSE3 (Beale-powell Restarts)	MSE4 (Scaled Conjugate Gradient)	MSE5 (Flecher-Reeves Restarts)
1	8.6490e-005	0.0007344	6.241E-05	9E-08	9.216E-05
2	9.4090e-005	7.84E-06	0.0003725	7.4E-05	0.0004285
3	4.4100e-006	0.0002434	4.356E-05	0.000812	1.849E-05
4	7.5690e-005	0.0001664	0.000222	0.000164	7.921E-05
5	3.9690e-005	0.000185	0.0001563	0.00156	5.929E-05
6	5.1840e-005	0.000529	0.000169	0.00257	0.0001464
7	7.2900e-006	1E-08	0.0002074	0.00062	0.0002756
8	3.6100e-006	0.0024602	0.0003204	0.001282	0.0003168
9	7.8400e-006	3.481E-05	0.000676	0.002079	0.0001769
10	1.6810e-005	0.0007563	7.29E-06	8.41E-06	6.4E-05

Five different variants of back propagation training algorithms are used for calculating MSE(mean square error) and MAPE (mean absolute percentage error) for DGS-LPF design. As shown in table 2 that MSE of trainlm is minimum among the five training function. MAPE of Levenberg-Marquardt Training Algorithm is 0.1754%, similarly MAPE of the Fleatcher-Reeves Update is 0.39191 %, Polak-Ribiere Update is 0.5922%, Powell-Beale Restart is 0.4462% and Scaled Cojugate Gradient is 0.8338% respectively. As it can be seen clearly that mean absolute error percentage is minimum for trainlm training function therefore in further result analysis this function is discussed in detail.

VI. RESULT

By analysing the output obtain from both the tools. In CST Studio we analyze the graph of S parameter to see the cut off frequency obtain the following S parameter graph by changing the dimension of DGS Low pass filter and observe the changes in cut off frequency or transition band of low pass DGS filter. Figure: 3 shows three S_{21} graph which clearly shows that how the cut-off frequency of the LPF decreases as we change L1 and L2.This graph also depict the fact that as we increase the lengths of defected structure the transition band also decreases.

When we train our DGS low pass filter by using feed forward back propagation network through trainlm transfer function we notice that training completes in 42 epochs and the training time is 1 sec. to achieve minimum Mean Square Error (MSE).

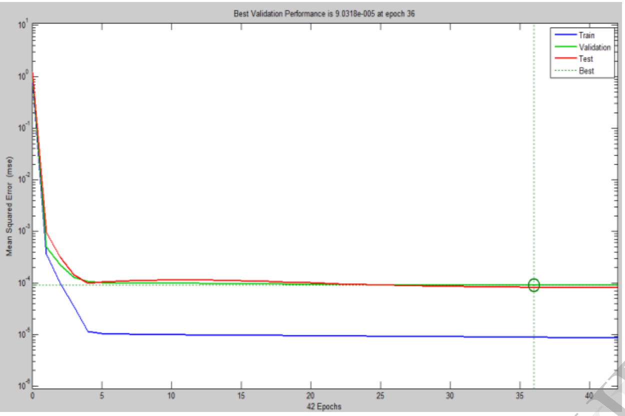
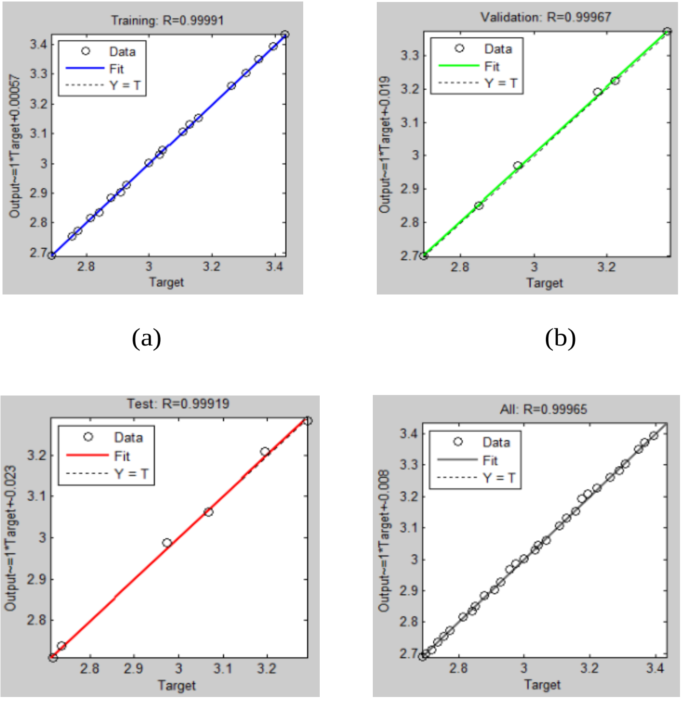


Figure 5: Performance graph indicating MSE

Figure 5 shows the training performance of the developed neural model for proposed DGS Low pass filter using L-M training Algorithm. Model is trained in 42 epochs and the training time was 1 sec. Figure 5 shows the plot of training, validation and test performances and the dotted line indicate the best performance for the validation data as seen from figure the best performance i.e. minimum MSE occurs at 9.0318e-005 at 36 epochs. The validation and test curves are very similar to each other. And if there is significant increase in the validation curve with respect to the test curve, then we can say that there is a possibility of some over fitting.

The training and validation sets are used during training. Once you are finished with training, then you run against your testing set and verify that the accuracy is sufficient. To show the relationship between the outputs of the network and the targets, the next step is to create a regression plot. When the network outputs and the targets are exactly equal, we will say that the training is perfect, but the relationship is rarely perfect in practice.



(a) (b)

(b) (d)

Figure 6: The three plots (a), (b) and (c) represent the training, validation, and testing data respectively. (d) Shows all three data set

The training, validation, and testing data are represented by three plots as shown in figure: 6, the perfect result – outputs = targets are represented by the dashed line in each plot. The best fit linear regression line between outputs and targets is shown by the solid line. The relationship between the outputs and targets is indicated by the value of R. If an exact linear relationship between output and target is indicated by R =1. When the value of R approaches to the zero then we can say that there is no linear relationship between outputs and targets. For this case, the validation and test results show R value, which is greater than 0.9 which implies that the training data indicates a good fit. If certain data points have poor fits, then this can be shown with the help of scatter plot.

VII. CONCLUSION

In this paper, the cut off frequency of DGS Low pass filter is analyzed with the help of CST studio and ANN tool by varying the dimension of defected ground structure. The results obtained with the present technique are closer to the experimental results generated by simulating the DGS low pass filter by using CST software on the FR4 (Lossy) substrate. The change in cut-off frequency and transition width is also noticed here by varying the dimension. The paper concludes that results obtained using present ANN techniques are quite satisfactory and followed the experimental trend and also that the Levenberg-Marquardt Training Algorithm is the best approach to train the network by MLPFFBP-ANN tool.

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