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Bandwidth Estimation of Microstrip Interdigital Band Pass Filter Using Artificial Neural Network

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***Abstract*—- In this paper effect of variation of substrate material on the band pass characteristics of the filter has been presented using artificial neural networks for desired frequency range between 1 - 2.5 GHz. Interdigital filter geometry using microstrip finger like compact structure used for better performance of filter design . An ANN model has been developed and tested for the band pass filter design and performance comparison of the EM simulated result with ANN is evaluated in terms of mean square error and concluded that RBF network is more accurate than other back propagation algorithms .The proposed method of design provide the parameters required for design at particular frequency range without using laborious calculation.**

Keywords- Artificial neural networks (ANN), feed forward back drop, CST, Interdigital capacitor (IDC), Mean square error (MSE), Radial Basis Function (RBF).

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1. INTRODUCTION

Microstrip filter are most popular as they can be fabricated by photolithographic process and easily integrated with other active or passive devices, hence highly desirable miniature communication systems. Interdigital filter is multifinger periodic structure which offer compact filter design space with very high Q value widely used in the high-frequency microwave circuits. [1–9]
In present days neural network models are used extensively for wireless communication engineering, which eliminates the complex and time consuming mathematical procedures [2]. An artificial neural network (ANN) model for a circuit can be established by learning from microwave data which is acquired by measurement and simulation results, through a process called training. [2] Once the ANN is trained, it can be applied for microwave filter design to provide instant answers to tasks it learned, thus eliminates the complex and time consuming mathematical procedures [3].
An ANN model based on Radial basis function and Feedback propagation algorithms are used to train the network and in order to compute the bandwidth of the filter for desired frequency range of 1.0-2.5 GHz. The paper provides the effects of substrate value on bandwidth of the filter for same physical design parameter.

2. DESIGN OF FILTER

The interdigital capacitor (IDC) is an element for producing a capacitor-like high pass characteristic using microstrip lines used for filter design. Number of Fingers/Resonators (N) provide coupling between the input and output ports across the gaps. Typically, the gaps between fingers and end of the fingers are equal to reduce parasitic capacitance. Since the conductors are mounted on a substrate, its characteristics will also affect performance. Most important parameter for design are height of the substrate (h) and its dielectric constant (Ɛr). The length (L) and width (W) of the finger determined total capacitance and capacitance per unit length along the width of the finger. Substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element. [6-7].

The total capacitance of an interdigital structure, expressed as:

$$C = (\varepsilon_r + 1).\, l\, [(N-3)\, A1 + A2] \qquad (1)$$

For a finite substrate, the effect of *h* must be included in A1 and A2 [5 - 9].
In the final design, usually $S=W$ and, $l \leq \lambda/4$. Approximate expressions for $A1$ and $A2$ are as:

$$A1 = 4.409 \tanh [0.55(h/W)^{0.45}] \times 10^{-6} \qquad (2)$$

$$A2 = 9.92 \tanh [0.52(h/W)^{0.50}] \times 10^{-6} \qquad (3)$$

$$Cs = 0.5 [(\varepsilon_r)^{0.5}/Zo.C] \qquad (4)$$

$$L = Zo. [(\varepsilon_r)^{0.5}/C].l \qquad (5)$$

Figure1, shows the proposed filter with N=10, Fingers/Resonators was designed to work for frequency range of 1 – 2.5 GHz with length of finger L=34mm, width and spacing of finger W=S=2mm respectively .The length and width of the filter design are calculated by the given equation (1), (2), (3), (4) & (5).

As capacitance value depends on the effective substrate of the material so, substrate values are change for the range, Ɛr = 3 to 13.2 to obtain the response such that it can be used to train the neural network and estimate the bandwidth of the filter for any substrate material in the frequency range for specific design parameter [11].

Center frequency, Fc and bandwidth, BW are the output of CST simulation result obtains by providing the physical design parameter height (h), width (W) and substrate (Ɛr) as input to network.

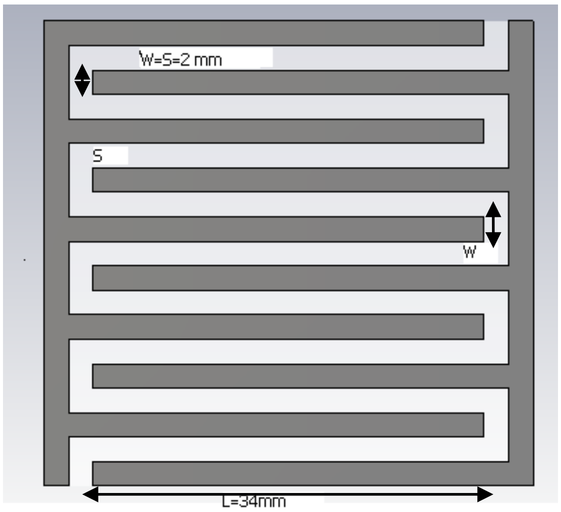

Figure 1: Proposed Interdigital band pass filter

The insertion loss and return loss for entire simulation results remain less than -1db and -27db respectively which shows the better performance of band pass filter over the frequency range of simulation.

3. ANN MODEL FOR ANALYSIS OF BAND PASS FILTER

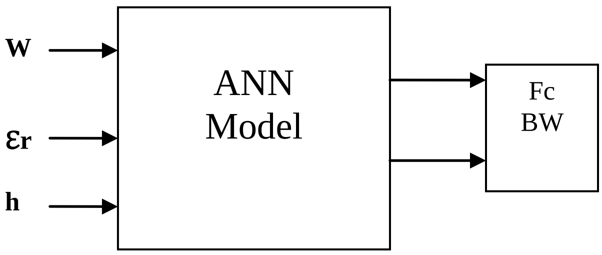

Figure 2. ANN model for estimation of bandwidth

The ANN model developed for Microstrip band pass filter is shown in Figure2.The feed forward network and radial basis network has been utilized to calculate the center frequency and bandwidth of the filter by providing height (h), width of strip, (W) and substrate ,(Ɛr) as input to network and center frequency and bandwidth as the output of network. In order to evaluate the performance of network using different algorithms 100 input-output training patterns and 15 testing patterns are used to validate the model.

4. NEURAL NETWORK ARCITECTURE

For present work two layers feed forward back propagation with three different training algorithms and Radial basis Function (RBF) is used to design the neural network for band pass filter.

4.1 MULTI LAYER FEED FORWARD BACK PROPAGFATION (MLFFBP) NEURAL NETWORK

For present work the feed forward back propagation network with one hidden layer are trained by three different algorithms to achieve the desired output i.e. center frequency, "Fc" and bandwidth of filter, "BW" with unparalleled accuracy. The input to network is substrate value "Ɛr", width of interdigital filter, "W" and height of substrate, "h". The internal weights of the network are usually computed by the training algorithm for best performance. In order to evaluate the performance of ANN the results are compared with the simulation results obtain using CST Microwave studio and the performance are compared on basis of mean square error generated from test results.

The transfer function preferred is tansig and purelin in the network with error goal 0.001 and learning rate 0.1. The MLFFBP network for all algorithms was trained with 100 samples and tested with 15 samples.

Center frequency and bandwidth obtain using CST Software [8] are compared with ANN results obtained using feedback propagation algorithms for performance evaluation of best training algorithms.

Figure 3 shows the comparison result of training algorithm used for testing of neural network. It is concluded that Levenberg – Marquaradt (LM) is most suitable learning algorithm for feed forward back propagation neural network as output of network for both Bandwidth and Center frequency is minimum for LM algorithm.

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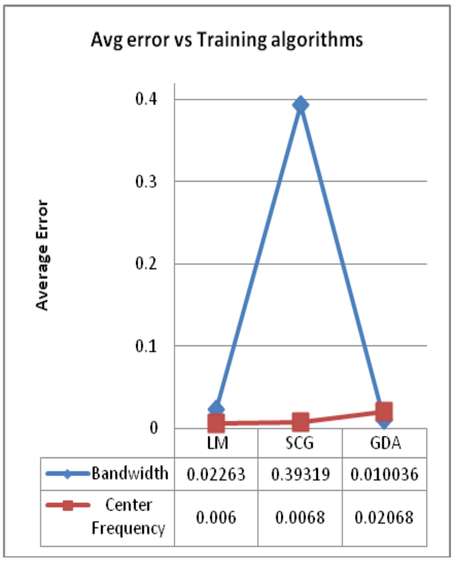

Figure 3: Graph showing variation of Average error on testing data set for different back propagation training algorithms.

4.2 RBF NETWORK

Radial basis function is feed forward neural network with single hidden layer that uses radial basis activation function for hidden neurons**.** It consists of three layers of neurons - Input, hidden and output. The hidden layer neuron represents a series of centers in the input data space. Each of these centers has an activation function, typically Gaussian. [4]
In the RBF network, the spread value was chosen as 1.3, which gives the best accuracy. The network was trained with 100 samples and tested with 15 samples. RBF networks are more fast and effective as compared to MLPFFBP for proposed Filter design. The RBF network automatically adjusts the number of processing elements in the hidden layer till the defined accuracy is reached. The training algorithm is unsupervised k-means clustering algorithm. Figure 4 shows the training performance of the neural network model is trained in 75 epochs with MSE = 2.64185e-005.

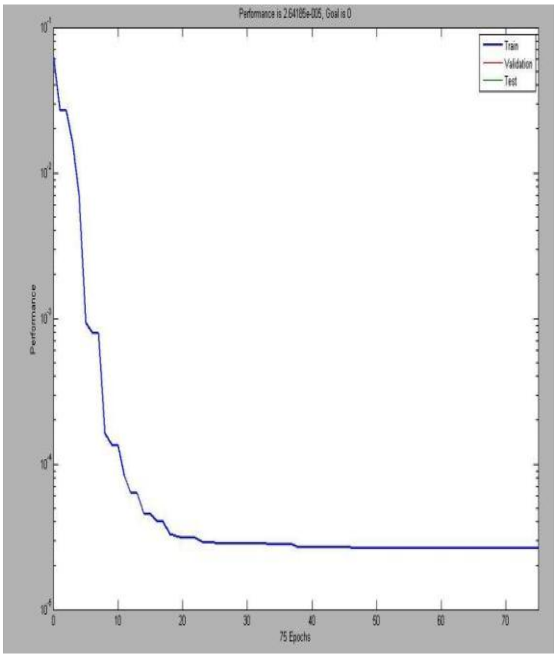

Figure 4: Number of epochs to achieve minimum mean square error level in RBF Network.

5. RESULT

An ANN model for finding the bandwidth of the filter has been designed and tested with different algorithms. It has been found that the Levenberg-Marquardt algorithm and Radial basis function is the optimal model to achieve desirable values of accuracy. [12]
Simulated results for LM and RBF network are compared in Table 1 shows the comparison results of MLFFBP ANN and RBF ANN based on mean square error of output bandwidth.
The value of substrate yielding output calculated by ANN is close to the target value. Thus, neural network gives approximately same design parameters as obtained by calculation. It has been observed that MSE low to a value - 0.00012 with Levenberg-Marquaradt (LM) training algorithm using tansig as a transfer function is achieved.
Achievement of such a low value of performance goal (MSE) indicates that trained ANN model is an accurate model for designing band pass filter.
Figure.5 shown below provides best simulation result of ANN close to simulated CST result by comparing the outputs and found that RBF neural network is more accurate for given range of simulated frequency than LM training algorithm. Average mean square of LM network is -0.0016 whereas that of RBF network is 0.000218 for simulated set of input data range.

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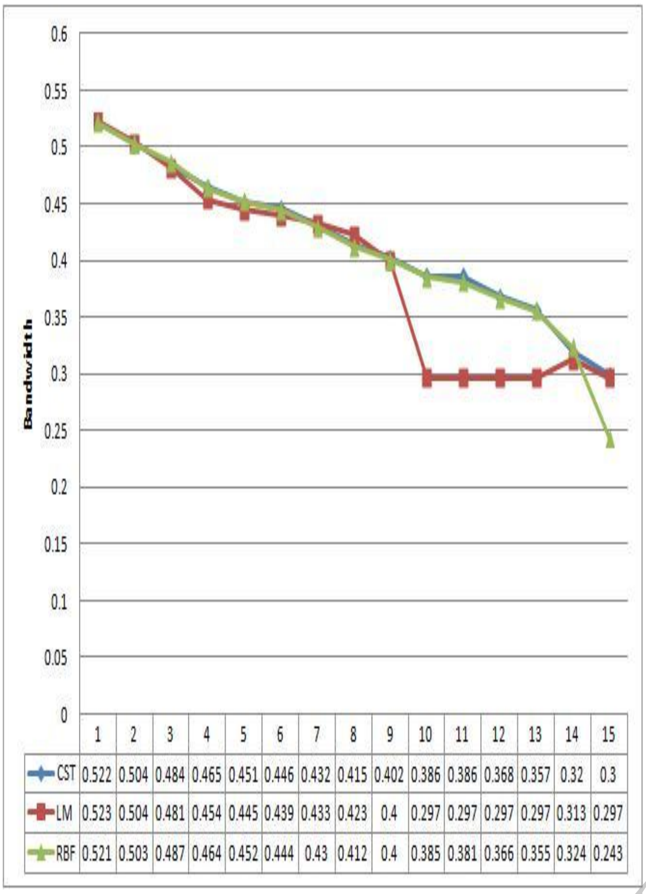

Figure 5: Graph showing variation of artificial neural network results with CST simulated result.

Table 1: Comparison of results obtained using CST with Levenberg-Marquaradt and RBF neural network for analysis of Bandwidth of filter.

T	BW(GHz) CST "A"	BW(GHz) ANN-LM "B"	BW(GHz) ANN-RBF "C"	MSE (A-B)	MSE (A-C)
3.4	0.5215	0.52297	0.52124	-2.1E-06	6.76E-08
3.9	0.5038	0.50356	0.50282	-5.76E-08	9.6E-07
4.3	0.4842	0.48133	0.48679	-8.23E-06	6.7E-06
4.9	0.4649	0.45375	0.46428	-0.00012	3.8E-07
5.2	0.451	0.44496	0.45221	-3.6E-05	1.4E-06
5.5	0.4463	0.43899	0.44411	-5.3E-05	4.7E-06
6	0.4315	0.43318	0.42969	-2.8E-06	3.2E-06
6.7	0.4145	0.42272	0.41207	-6.7E-05	5.9E-06
7	0.4018	0.40002	0.40009	-3.1E-06	2.9E-06
7.7	0.3864	0.29678	0.38529	-0.0080	1.2E-06
8	0.3863	0.2967	0.38101	-0.0080	2.7E-05
8.7	0.3683	0.2967	0.36632	-0.0051	3.9E-06
9.2	0.357	0.2967	0.35548	-0.0036	2.3E-06
12	0.32	0.31279	0.32377	-5.1E-05	1.4E-05
12.7	0.2999	0.2967	0.24335	-1.0E-05	0.0031

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6. CONCLUSION

An efficient and time saving method for calculation of bandwidth of filter is shown using ANN. In the analysis, one can acquire to choose the exact value of substrate based on geometry to obtain the working center frequency and bandwidth. The mean absolute percentage error for LM training is 2.256 % whereas for RBF network is 0.512 % which shows that experimental results generated by radial basis method is more accurate than other feedback propagation technique over the test input range.

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