Abstract:

In this article a suspended strip line filter design, modeling and optimization using artificial neural network (ANN) technique is described. ANN is widely used in microwave filter analysis and synthesis. ANN technique can reduce the cost of computation significantly and thus can produce fast and accurate result compared to the conventional electromagnetic (EM) methods.

The synthesis of band pass filter is done using the coupled suspended strip line resonators in end coupled configuration. The method developed is verified from FEM simulation. Finally the filter has been fabricated and tested to verify the theory. The measurement of the filter in this configuration gives a wide pass band and significant low loss VSWR over the frequency band of design.

Introduction

Neural network techniques have been recognized as a powerful tool for microwave design and modeling problems. It has been applied to various microwave design applications [1], [2] such as vias and interconnects [3], embedded passives [4], coplanar waveguide components [5], transistor modeling [6]–[8], noise modeling [9], power-amplifier modeling [10], analysis of multilayer shielded microwave circuits [11], nonlinear microwave circuit optimization [12], etc. Different algorithms can be developed combining NN and optimization method for faster and accurate filter solution. A Neuro-genetic algorithm has been developed for optimization of suspended strip line filter [20]. NN models can be combined with genetic algorithms to synthesize millimeter wave devices like filters. The method has been used to synthesize band pass filters in suspended strip line filter configuration.
The ANN method provides fast and accurate results and reduces the computational costs associated with a time consuming EM solver in the design of microwave filters. These methods can be used in combination with standard filter design methods to design complex microwave filters. It helps to improve the speed and accuracy of filter design for communication circuit and systems.

Neural networks have the ability to model multidimensional nonlinear relationships. The evaluation from input to output of a trained neural network model is also very fast. These features make neural networks a useful alternative for device modeling where a mathematical model is not available or repetitive electromagnetic (EM) simulation is required. Once a model is developed, it can be used over and over again. This avoids repetitive EM simulation where a simple change in the physical dimension requires a complete re-simulation of the EM structure.

![Fig 1. Generalized Chebyshev Synthesis model of the SSL filter](image1)

![Fig 2. Cross-section of the broadside-offset coupled strips in suspended strip line configuration](image2)

![Fig 3. FEM Model of the SSL Filter](image3)
Fig. 4: S parameter of a single section of SSL filter

Fig. 5: NN model for optimization of SSL filter
**Fig. 6:** 15 section Suspended strip line filter model

**Fig. 7:** Simulation result of SSL filter
Finite Element method (FEM) is employed for evaluating the response of structure under analysis and an optimization algorithm is used to improve the design in order to reach the desired filter performance. The optimization process involving ANN model is used for calculating the quasi-static parameters of suspended strip lines. These models are basically developed by training the artificial neural networks with the numerical results of quasi-static analysis. Neural models were trained with two different learning algorithms to obtain better performance and faster convergence. When the performances of neural models are compared with each other, the best test results are obtained from the multilayered perceptrons trained by the Levenberg-Marquardt algorithm.
For the neural network model of the suspended strip line under consideration, the inputs are the relative permittivity of substrate materials $\varepsilon_r$ and geometrical dimensions like normalized cavity height, substrate dielectric constant, normalized strip width and the outputs are the effective permittivity ($\varepsilon_{eff}$) and characteristic impedance ($Z_0$). ANN models are a kind of black box models, whose accuracy depends on the data presented to it during training process. A good collection of the training data, i.e., data which is well-distributed, sufficient, and accurately simulated, is the basic requirement to obtain an accurate model. For microwave applications, there are two types of data generators, namely measurement and simulation.

The aim of the training process is to minimize the training error between the target outputs and the actual outputs of the ANNs. Training the ANNs with the use of a learning algorithm to calculate the effective permittivity and characteristic impedances of suspended strip line involves presenting them sequentially and/or randomly with different sets of input parameter set and corresponding output parameter as effective permittivity ($\varepsilon_{eff}$) and characteristic impedances ($Z_0$). ANN outputs are compared to the known outputs of the training data sets and errors are computed. Error derivatives are then calculated and summed up for each weight until all the training data are fed to the network. These error derivatives are then used to update the weights of neurons in the models. Training proceeds until errors are lower than prescribed values. Currently, there is no deterministic approach that can optimally determine the number of hidden layers and the number of neurons. A common practice is to take a trial and error approach which adjusts the hidden layers to strike a balance between memorization and generalization. After several trials, it was found that three hidden layered and two hidden layered networks were achieved the task in high accuracy for suspended strip line filter. The numbers of neurons were 6 for the input layer, 6, 10 and 6 for the first, the second and third hidden layers and 2 for the output layer. The tangent sigmoid activation functions were used in the first hidden layer, the sigmoid activation functions were used in the other logarithmic sigmoid activation functions were used in the first and second hidden layers, respectively. The linear activation function was used in the input and output layers in the neural models for the suspended strip line structure.

**Measurement**

The filter has been fabricated using suspended strip line configuration with 15 section and properly integrated before measurement by VNA. The measured result shows more or less 80% bandwidth (18.0-40.0 GHz.) with an insertion loss of 2.0dB (average) over the band. The average VSWR over the band is 1.5. So a broadband filter with low insertion loss and sufficiently miniaturized design optimization has been done using ANN.
The ANN method provides fast and accurate results and reduces the computational costs associated with a time consuming EM solver in the design of microwave filters. These methods can be used in combination with standard filter design methods to design complex microwave filters. It helps to improve the speed and accuracy of filter design for communication circuit and systems.

References:

10. Fedi, G., S. Manetti, G. Pelosi, and S. Selleri, Design of cylindrical posts in rectangular waveg-


22. Li, M., X. Li, X. Liao, and J. Yu, Modeling and optimization of microwave circuits and devices

