Small Signal and Large Signal Modeling of HBT's Using Neural Networks

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Abstract- **This paper presents the small signal and large signal models for an AlGaAs and a SiGe Heterojunction Bipolar Transistor, using neural network techniques. The main advantage of this technique is the wide range of frequencies over which the small signal model is valid and the great accuracy of the large signal characteristics. Both the models have been verified by comparing the simulated values with the measured ones of the HBTs for both the material systems.**

Keywords – **HBT, Neural Networks, Modeling**

I INTRODUCTION

A new breed of microwave CAD algorithms based on the neural network computing paradigm have been investigated by researchers and have shown promising results for different applications such as the modeling of transistor behavior and microwave circuits. In comparison with other statistical and curve-fitting approaches for predicting system behavior, this method uses a learning process which fine-tunes neural network parameters to interrelate the variables being modeled. In this research, we have investigated the modeling of HBTs using neural networks. In the preliminary investigation, the small signal and large signal characteristics of AlGaAs and SiGe HBTs. have been modeled using neural networks.

II NEURAL NETWORK MODEL

We have based our neural network model on the multi-layer (one input layer, one hidden layer, and one output layer) feed-forward architecture. The size of the vector in the hidden layer is determined by the number of inputs and outputs that we have chosen. A training set of data is used to then model the network. The learning rate is set, and the neural network model is subjected to an initial set of weights. The model is trained using the back-propagation training algorithm. The outputs are then evaluated based on this initial set of parameters. The back-propagation algorithm is then used to adjust the weights so as to minimize the mean squared error of the outputs. A seemingly fast mapping from the inputs to the corresponding output variables is achieved. Once the model is ready, it is verified by being subject to a new set of input data. The outputs of the models that were obtained appear to agree very well with the experimental set of data. We successfully developed two different neural network models, one for the large signal and another for the small signal, for both the AlGaAs and SiGe HBTs.

III SMALL SIGNAL AND LARGE SIGNAL MODEL

The small signal model has 3 input variables (frequency, V_{ce} and I_b), and 8 output variables (the normalized magnitudes and phases of the scattering parameters). A large number of scattering parameter data, measured at various frequencies and biases, was used to train this neural network model, using the back-propagation algorithm mentioned in the previous section. This model was then used to get the scattering parameter values for various bias values different from the ones in the data set used for training. The simulated results were compared with experimentally measured results. Similarly, the large signal model was developed using the Gummel Poon plots and DC I-V characteristics.

IV RESULTS

The small and large signal models were used to simulate the HBT characteristics, and compared to the experimentally measured characteristics. The results can be seen in the figures that follow. The simulated and measured S parameters for AlGaAs and SiGe HBTs are shown in figures 1 and 2 respectively at a fixed bias. It can be seen that there is excellent agreement of our model with the measured values. Figures 3 and 4 show the comparison of our large signal model with the experimental values of the DC I-V characteristics and the Gummel Poon plots (for the collector and base currents) for the AlGaAs HBT. The comparisons of these same characteristics for the SiGe HBT are shown in figures 5 and 6. It can be seen that our model matches the measured values with great accuracy. This verifies our small signal and large signal models for both the materials used for the HBTs.

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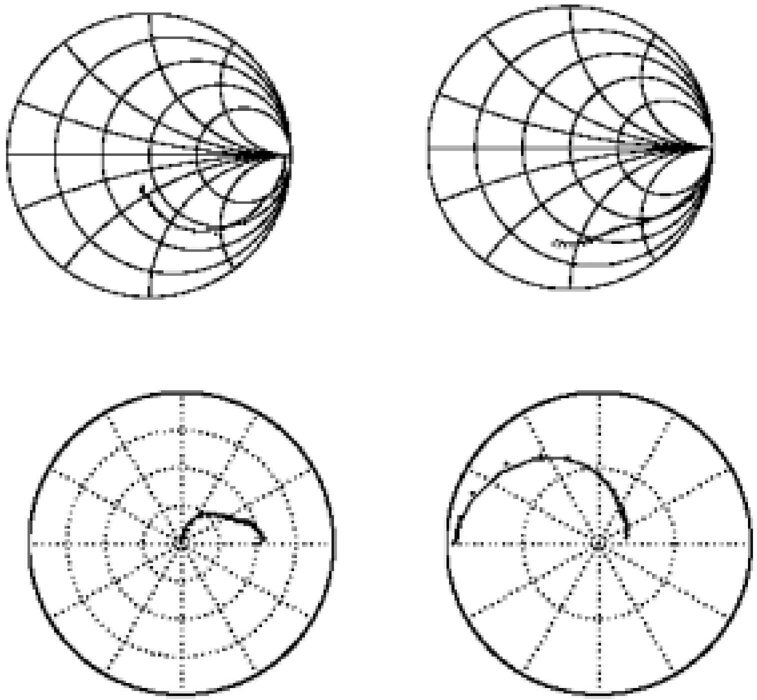

Fig. 1. S parameters for AlGaAs HBT at Vce = 1.5V, Ib = 56uA

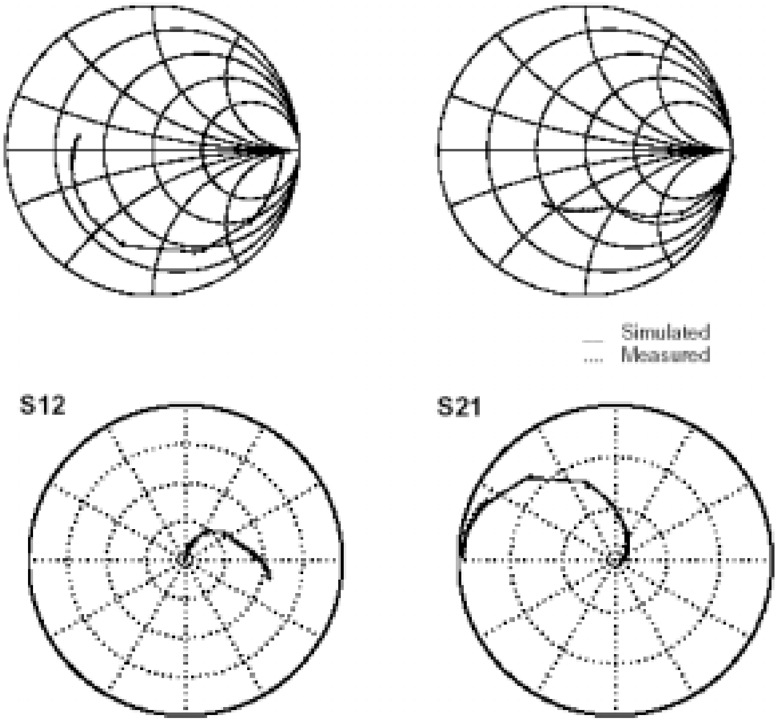

Fig. 2. S parameters for SiGe HBT at Vce = 1.9V, Ib = 53uA

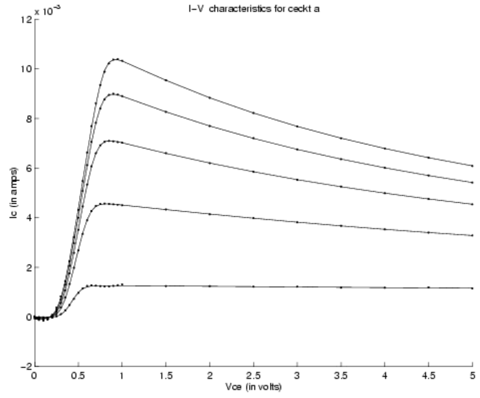

Fig. 3. DC I-V characteristics for AlGaAs HBT

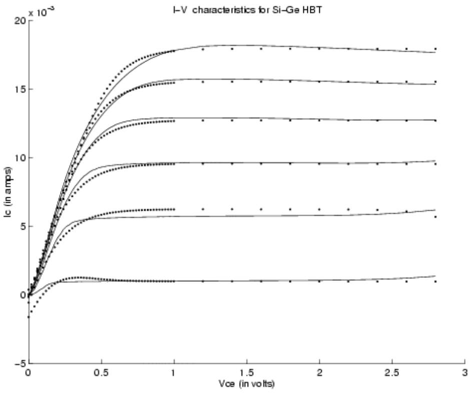

Fig. 6. DC I-V characteristics for SiGe HBT

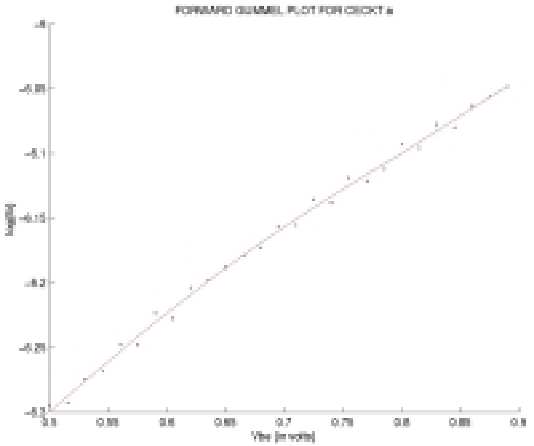

Fig. 4. Forward Gummel (I_b) plot for AlGaAs HBT

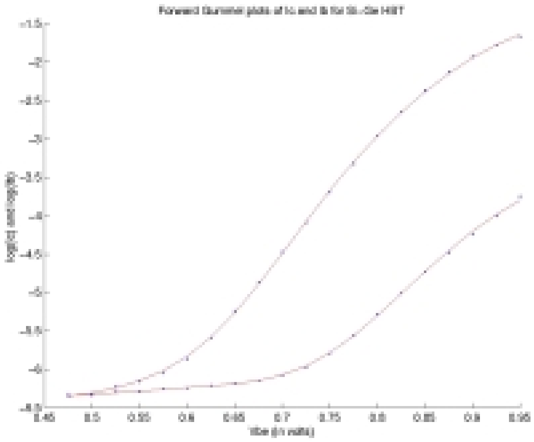

Fig. 7. Forward Gummel Poon plots for SiGe HBT

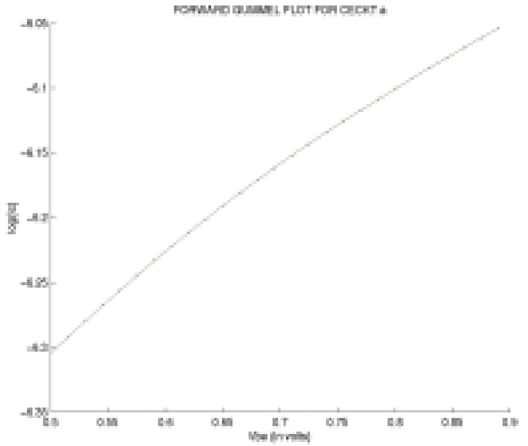

Fig. 5. Forward Gummel (I_c) plot for AlGaAs HBT

V CONCLUSION

In conclusion, the neural network has been used to model the small signal and large signal characteristics of HBTs effectively. Also, the modeling technique works very well regardless of the material system. At present, there is ongoing work to use this technique in the implementation of amplifiers and other circuit applications.

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