Distributed Small Signal Modelling for Multi-port GaAs FETs

Zhong Zheng [1], Ooi Ban Leong [1]
Department of Electrical and Computer Engineering
National University of Singapore
elezhon@nus.edu.sg

1. Introduction

The design of Microwave and Millimeter-wave Monolithic Integrated Circuits (MMIC) requires a meaningful and accurate characterization of the electron device along with information about the changes caused by the process parameter variations. Meanwhile, increasing application of multi-port GaAs FETs, adopted for side-biasing in the higher level of MMIC integration, has led to increased research focus on its modeling.

However, conventional lumped models, based on simple linear rules or completely empirical expressions may not be sufficiently proper at relatively high operating frequencies. One of the main problems is related to the limitation of the lumped description of intrinsically distributed phenomena such as the coupling effect caused by metallic stripes and grounded vias. Moreover, their side-biasing ports also can not be well modeled by those conventional methods. Therefore, the transistor must be distributed as both the parasitic phenomena and the intrinsic elements to achieve precisely modeled especially in high-frequency domain.

This paper presents a novel approach to multi-port distributed modeling for GaAs FETs with different multi-fingers and physical structures (Fig. 1), which describes the GaAs FETs based on the electromagnetic field theory and circuit analysis.

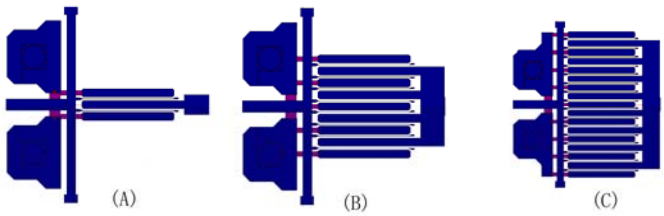

Figure1: Various types of multifinger GaAsFETs (A) 2-finger; (B) 8-finger; (C) 16-finger

The parasitic effect and material losses caused by the extrinsic region and fabricated structure are strictly calculated by the IE3D software, in the mean time its active part can be defined with the optimized modeling which will be introduced in the next section. Moreover, DC biasing ports of the transistors are also exactly presented by electromagnetic analysis.

2. THE DISTRIBUTED MODEL

The distributed model is composed by two parts; the first part, which models the electromagnetic effects in the extrinsic region, is shown in figure 2 below.

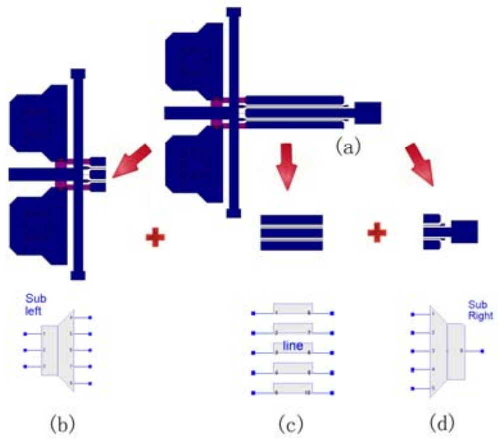

Figure 2: 2-finger transistor and its multiports models in IE3D

Here use 2-finger device for example (Fig. 2a). With IE3D software, the whole transistor is divided into several multi-ports models: input part (Fig. 2b), FET stripe channels (Fig. 2c) and output part (Fig. 2d), whose dimensions are identically the same with the measured 2-finger GaAs FET layout. Meanwhile, sufficient fine mesh cell is needed to prevent unambiguous oscillatory waveform. The other multi-finger GaAs FETs are simulated on same principle as 2-finger GaAs FET. The benefits of electromagnetic simulation are that it not only permits the prediction of the behavior of devices with various gate widths but also takes into account the influence of elements located near the active device and notably the source vias [1]. This method not only allows the extrinsic elements of the GaAs FETs to be predicted and also gives the possibilities to investigate the behavior of extrinsic parasitics using an extraction process similar to the cold FET technique [2]. The second part, which is the active region of the device, is modeled with GaAs FETs equivalent circuit. Each pair of gate fingers has been described as one single transistor with passive elements (Fig. 3).

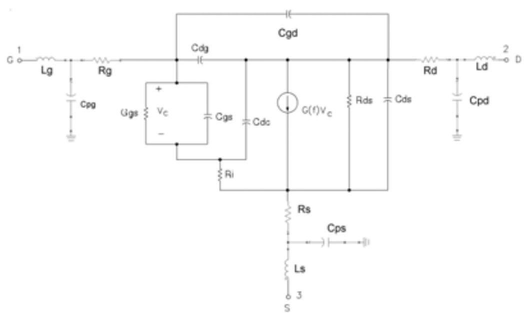

Figure 3: equivalent circuit of each pair of gate fingers

So the 2-finger FET is presented as 2 devices connected in parallel to the gate and drain. To further describe the transistor, it would be sliced in to N sub-transistors whose dimensions are much smaller than operated wavelength so the absorbed current caused by each long finger can be effectively eliminated. The active value of those cells could first be roughly obtained by the conventional methodology [3] and finally fixed with ADS optimized procedure. As we mentioned in the last paragraph, the effect of side-biasing ports is calculated by their exact dimension using electromagnetic analysis.

The final step of modeling is to combine the above two parts into one practicable device in ADS. The first part, exported from IE3D as several data items, is connected with the equivalent active circuits obtained by ADS. As can be seen below (Fig. 4), the final model of this 2-finger GaAs FETs is a 5-port symbol which can be used in further MMIC design.

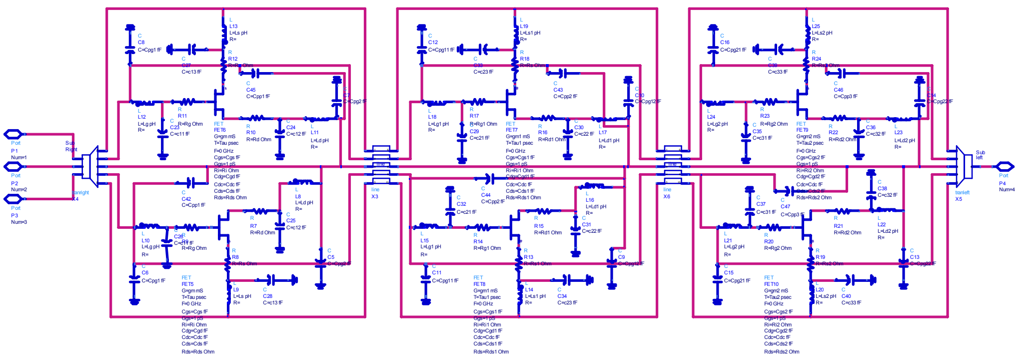

Figure 4: Contributed model of 2-finger GaAsFET

3. Measurement and Simulation Results

In order to verify the accuracy of the above method, we present the comparison between measured and simulated small signal parameters from 3 types of multi-finger GaAs FETs. The transistors were measured with 50-Ohm input/output impedance related to the bias Vgd=7V and Vgs=-0.3V from 1 to 20 GHz. In Fig. 6-11, the varied diagrams show very good agreements with simulated results in pulsed S-parameter of various transistors.

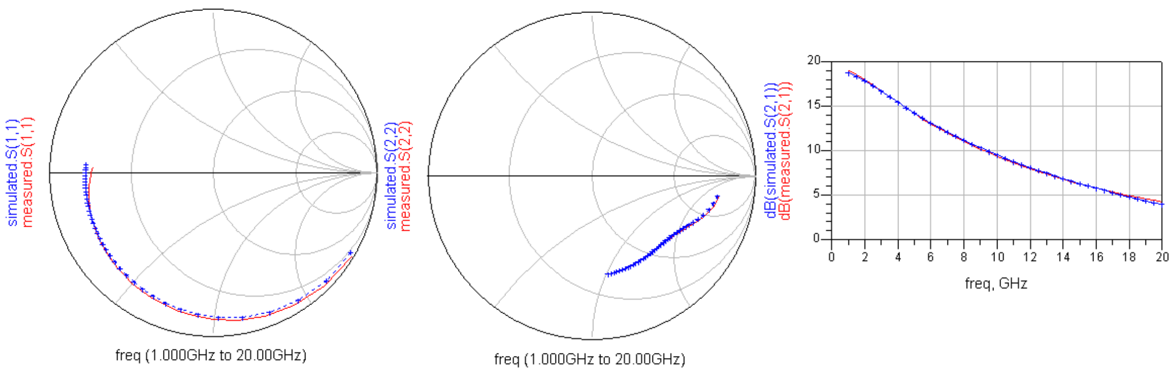

Figure 5: Comparisons between measured and simulated S-parameters of 2-finger device (cross: simulated data; line: measured data)

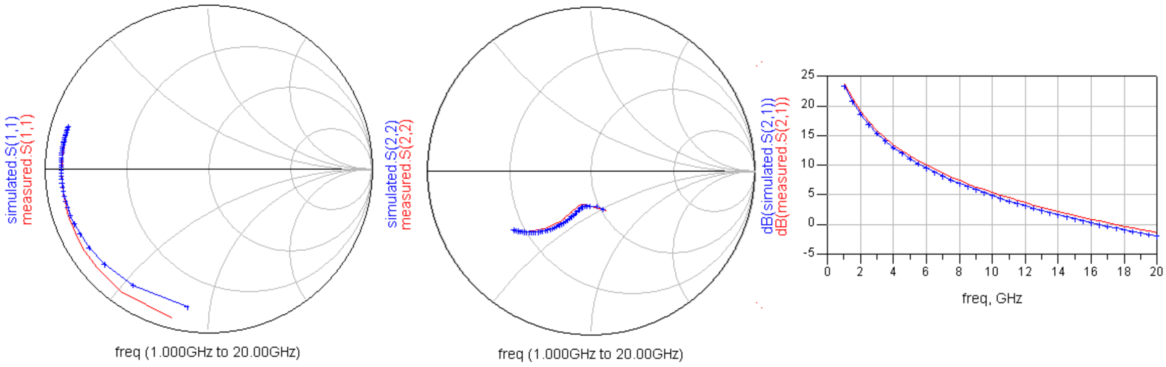

Figure 6: Comparisons between measured and simulated S-parameters of 8-finger device (cross: simulated data; line: measured data)

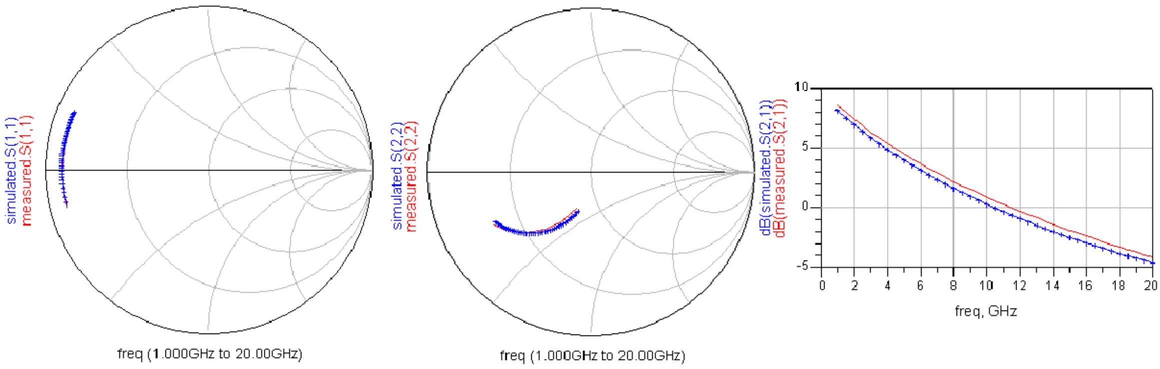

Figure 7: Comparisons between measured and simulated S-parameters of 16-finger device (cross: simulated data; line: measured data)

4. Conclusion

In this paper, a distributed approach to the modeling of multi-port GaAs FETs has been proposed, with the aim of providing an accurate and efficient tool for MMIC design. The modeling approach is based on accurate electromagnetic simulation of the electron device with distributed cells. Small signal parameters measurement and simulation have been compared, which show a very good performance of this distributed model.

References

[1] E. Larique, S. Mons, D. Baillargeat, S. Verdeyme, M. Aubourg, R. Quere, P. Gui-lon, C. Zanchi, J. Sombrin, “Linear and Nonlinear FET Modeling Applying an Electromagnetic and Electrical Hybrid Soft-ware”, IEEE Trans, Microwave Theory & Tech., vol. 47, no.6, pp. 915-918, June 1999.

[2] G. Dambrine, A. Cappy, F. Heliodore, E. Playez, “A New Method for Determining the FET Small Signal Equivalent Circuit”, IEEE Trans. Microwave Theory & Tech., vol. 36 no. 7, pp. 1151-1159, July 1988.

[3] Manfred Berroth and Roland Bosch, “High-Frequency Equivalent Circuit of GaAs FETs for Large-Signal Applications”, in IEEE Trans. On Microwave Theory and Tech., vol. 39, NO. 2, February, 1991, pp. 224–229.