Genetic Algorithm-based Parameter-Extraction for Power GaAs MESFET

Yifan Gao[1]

Abstract - **A modified genetic algorithm is presented for parameter extraction of small signal equivalent of microwave power GaAs MESFET. A new approach of genetic algorithm-based model in the paper is applied to determine the equivalent circuit elements of GaAs MESFET directly from measured S-parameters biased in the active region. The results of calculation show that the method presented is suitable for microwave application**

Keywords - **Genetic algorithm, model, small signal, MESFET**

I. INTRODUCTION

A key step in the construction of lumped-element nonlinear models is the extraction of small-signal S-parameters at different bias settings [1-4]. Fig. 1 shows the 13-element small-signal model that is most often used to describe the GaAs MESFET. Until recently, the extraction of this model was performed using standard gradient and random optimizers or with the aid analytical techniques. The first approach can lead to nonphysical and non-unique solutions [2], while the second relies on additional measurement steps or special structures. Analytical methods are faster than optimizer-based methods, but they are susceptible to measurement errors and their implementation is device specific. In the latest years, the new parameter-extraction methods have been published [5-10], which strive to overcome these limitations. All extraction techniques reduce the dimensions of the optimization problem to improve robustness and efficiency by using a bi-directional multi-plane search.

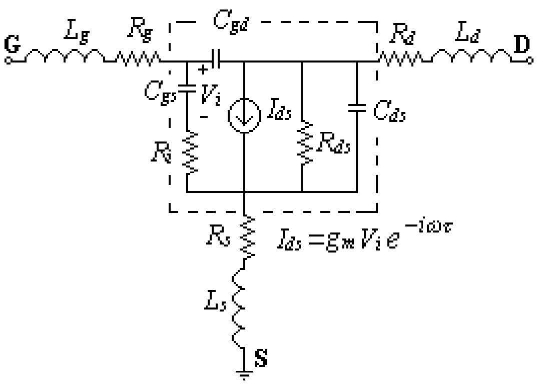

Fig. 1 Schematic of a small signal distributed Model

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II. GENETIC ALGORITHM

The genetic algorithm-based parameter extraction was used to solve the problem. The genetic algorithm [11] is a method used to solve problems such as optimizations with a computer simulation of the evolutionary process of the population of virtual creatures. A virtual creature has a chromosome that determines its degree of fitness to a particular habitat. This chromosome is composed of a set of genes.

If the population includes N_M members, the *i*th individual has a chromosome G_i and the fitness value f_i defined as

$$G_i = \{g_0^i, g_0^i, \cdots, g_{N_g-1}^i\} \tag{1}$$

and

$$f_i = f(G_i) \tag{2}$$

where g_j^i (j=0, ⋯, N_{g-1}) denotes each gene, and N_g is the number of genes in one chromosome. Function f_i in Eq. 2 calculates the fitness values of the chromosome, which changes according to the typical problem of application. The genetic algorithm can be summarized as follows:

Step1: generate initial populations, let generation equates zero.
Step2: Evaluate fitness values and rearrange individuals.
Step3: Natural selection, weed out small percent of population.
Step4: Reproduction and generate mutants.
Step5: If generation doesn't equate to N_{gen}, then return to Step 2 and let generation increase gradually. Otherwise print the calculation results.

We generate an initial population composed of N_M individuals and initialize the chromosome of each with random values. Then we determine each individual's fitness and rearrange it in order to increase fitness. The population undergoes natural selection, reproduction and the succession of generations. If any population adequately fits the conditions or the number of generations reaches its maximum value, then get out of the loop among steps 2-4.

III. IMPLEMENTATION AND RESULTS

We employed this concept to extract small-signal equivalent circuit elements of microwave power GaAs MESFET. The equivalent circuit is composed of 13 lumped elements and valid over the adopted frequency range of measurements, 13-element values are obtained directly from measured S-parameters biased in the active region. Measurements of S-parameters ranging from 0.1 to 10GHz at more than 10 different bias points□application of single-cell 2100μm gate-width GaAs MESFET is presented.

The results of extrinsic and intrinsic elements extracted list in Table I, in which the biases (V_{ds}, I_{ds}) are (3V, 80%I_{dss}), (10V, 35%I_{dss}) and (10V, 7.5%I_{dss}), respectively. The values of the columns are obtained with the strategy approaches described above, in which all of errors are lower than 10^{-4}. Now the new method proposed could overcome the disadvantages of the conventional extractor mentioned in section I.

TABLE I

VALUES OF INTRINSIC ELEMENTS AND EXTRINSIC ELEMENTS

Bias settings / Elements	Final Value 3V, 80%I_{dss}	Final values 10V, 35%I_{dss}	final values 10V, 7.5%I_{dss}
R_g(Ω)	4.1589	4.1492	4.1571
R_s(Ω)	1.5483	1.5533	1.5450
R_d(Ω)	1.8159	1.8154	1.8210
L_g(nH)	0.51905	0.51883	0.51725
L_s(nH)	0.048153.	0.047891.	0.047931.
L_d(nH)	0.35171	0.35180	0.35177
C_{gs}(pF)	0.91170	0.93412	0.62813
R_i(Ω)	6.4894	7.4948	7.1713
C_{gd}(pF)	0.34116	0.20874	0.20891
g_m(mS)	88.866	55.954	24.871
τ(ps)	1.1671	1.2219	1.2616
C_{ds}(pF)	0.34318	0.17641	0.18321
R_{ds}(Ω)	16.311	21.425	17.791

The comparison between the measured and calculated S-parameters under the proposed method for 2100μm gate-width GaAs MESFET is presented in Fig. 2. The good agreement between the measured and calculated S-parameters is shown from Fig. 2. Besides, we use the new method to multi-bias extraction. The results show the values of relative error for extrinsic elements are lower than 3% in different bias setting. As for intrinsic elements, the values of relative error at the same biasing are lower than 1% within the measured frequency band.

IV. CONCLUSION

A new method is employed to extract model parameters of small-signal equivalent circuit for microwave power GaAs MESFET. The application results show that the agreement is good between the calculated values and the measurement data of MESFET.

All results presented in this paper have been generated with a compiled program of MATLAB software, a product of the Math Works Inc. The time of executing the program on PC Pentium II took about 5 minutes for one extraction. The method can provide more reliable, stable and accurate results than those of conventional methods.

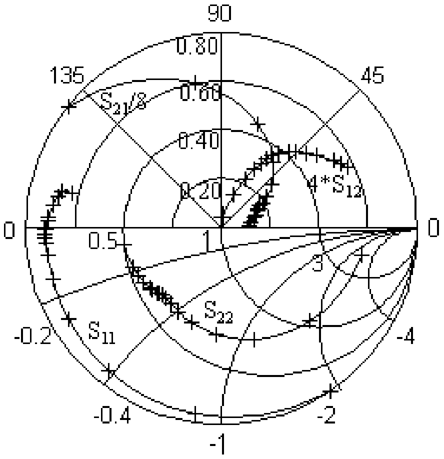

Fig. 2. S-parameters of 2100μm GaAs MESFET, Frequency: 0.1~10GHz. Bias setting: V_{ds}=3V, I_{ds}=80%I_{dss}. Solid-line: modeling values. Symbols +: measuring data.

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