Temperature in HFETs when operating in DC

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ABSTRACT

This work analyses the DC response of InGaAs channel Modulation Doped Field-Effect Transistors, when varying temperature from 300 to 400 K. An analytic model for the intrinsic drain current is derived from previous work, done for a similar AlGaAs channel device, in order to explicitly show the temperature dependence. The extrinsic resistances are numerically evaluated and added in a straightway form to the model. Experimental output characteristics at different temperatures of an InGaAs HFET in static operation are compared with those offered by the resulting extrinsic model and numerical simulations. Computed relative errors are around 10%.

Keywords: HFET´s, semiconductor device modeling, temperature, numerical simulations, static operation.

1. INTRODUCTION

InGaAs channel Heterostructure Field-Effect Transistor (HFET), having typical cut-off frequencies of various tens of GHz, exhibits excellent properties for ultra fast operation[1]. As result, a great number of applications in Microwave Monolithic Integrated Circuits (MMICs) are based on this transistor[2,3]. Typical temperatures of operation are moderate, from 300 to 400 K. Nevertheless, device characteristics of HFETs may significantly change in this range[4, 5].

The motivation of this paper is to find a fully physics-based model that predicts the temperature-dependent behaviour of InGaAs HFETs in static operation, but, at the same time, simple enough to be implemented in a circuit simulator such as SPICE.

Several models, including temperature dependence, have been previously published for intrinsic HFETs. However, even when they are physics-based, usually incorporate empirical parameters[6] or, if that is not the case, are applied to the more simple AlGaAs/GaAs system[7]. Anyway, the extrinsic resistances need to be measured and added later as external circuit elements to the overall simulation. Usually the extrinsic resistances are extracted at different temperatures in the linear region, assuming that in saturation their values are preserved[5, 8]. Furthermore, when simulated, the source and drain series resistences are assumed equal[5], without any consideration about the electron transport through the heterojunction that forms the channel[9].

The InGaAs HFET under study is presented in section 2. For this transistor we report in section 3 an analytical study of the intrinsic behaviour, derived from one presented for AlGaAs/GaAs[7]. The model is extended in a straightway form to incorporate the extrinsic resistances in section 4. Section 5 is devoted to emphasize the temperature dependences of the model parameters. To extract the extrinsic resistances at any operating biases, the HFET is numerically simulated in section 6, where results for the output characteristics derived from the model and simulations at different temperatures are compared with measurements. Finally, some conclusions are given in section 7.

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