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Modeling of Trap Induced Dispersion of Large Signal Dynamic Characteristics of GaN HEMTs

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Abstract—We propose here a non-linear GaN HEMT model for CAD including a trapping effects description consistent with both small-signal and large-signal operating modes. It takes into account the dynamics of the traps and then allows to accurately model the modulated large signal characteristics that are encountered in telecommunication and radar signals. This model is elaborated through low-frequency S-parameter measurements complementary to more classical pulsed-IV characteristics. A 8x75μm AlGaN/GaN HEMT model was designed and particularly validated in large-signal pulsed RF operation. It is also shown that thermal and trapping effects have opposite effects on the output conductance, thus opening the way for separate characterizations of the two effects.

Index Terms—Trapping effects, thermal effects, low frequency S-parameters, CAD non-linear model, RF pulsed operation.

I. INTRODUCTION

Gallium Nitride (GaN) High Electron Mobility Transistors (HEMTs) on SiC are now recognized as good candidates for the development of a number of RF applications and notably Power Amplifiers (PA) for telecommunication and radars, due to their high breakdown voltage, their high cut-off frequency as well as their high temperature capabilities. However they are still subject to parasitics effects such as thermal effects and especially trapping effects. Those trapping effects have been extensively studied using a number of techniques such as pulsed measurements, load-pull measurements as well as frequency dispersion measurements. At the same time, modeling trapping effects using a double charge trap model. This model is elaborated through low-frequency S-parameter measurements complementary to more classical pulsed-IV characteristics. A 8x75μm AlGaN/GaN HEMT model was designed and particularly validated in large-signal pulsed RF operation. It is also shown that thermal and trapping effects have opposite effects on the output conductance, thus opening the way for separate characterizations of the two effects.

II. IMPACT OF TRAPS ON LARGE SIGNAL CHARACTERISTICS

One convenient way to identify the impact of trapping effects is to monitor the average drain current of the transistor versus an increasing RF input power. It has already been reported in [1] and [3] that this drain current under class-AB conditions decreases as the input power increases, contradicting the expected characteristics. Clearly this behavior cannot be explained by thermal behavior as far as the channel temperature sinks when the power increases and would lead, at least for moderate powers, to an average drain current enhancement.
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Modeling of Trap Induced Dispersion of Large Signal Dynamic Characteristics of GaN HEMTs

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Abstract. We propose here a fast variational GaN HEMT model for a GaN including a trapping effects in a consistent with both multivalley and multiquantum well structures. It takes into account the dynamics of the traps and then allows to accurately model the measured signal characteristics that are encountered in intermittent and carrier sweeps. This model is extended through a frequency-dependent parameter measurements corresponding to the first classical pulsed-V characterizations. A GaN HEMT-S100 was designed and specifically fabricated to probe pulse pulsed R measurement. It also shows that thermal and trapping effects have opposite effect on dynamic characteristics and that the measured signals are highly sensitive to the trapping levels. Contrary to some previous works, the model we use for separating the characteristics of the two effects:

1. Introduction

Gallium Nitride GaN High Electron Mobility Transistors (HEMT) are now recognized as good candidates for the development of a number of RF applications and notably Power Amplifier (PA) for telecommunication and radars, due to their high breakdown voltage, their high cut-off frequency as well as their high temperature capabilities. Moreover they are not subject to parasitic effects such as thermal affects and especially trapping effects. Those trapping effects have been extensively studied using a number of techniques such as pulsed measurements, load pull measurements as well as frequency dispersion measurements. At the same time, models have been proposed to take these effects into account [1,2,3,4], and while the effects of traps are well taken into account in CW conditions, their impact on dynamic large signal characteristics remains difficult to understand. They manifest themselves under restricted signals such as RF pulses or telecommunication signals. Memory effects are the main consequence of these trapping effects. In this paper we propose to investigate the dynamics of these trapping effects using large signal load pull measurements as well as frequency dispersion measurements. It shall be shown that a constant nonlinear model can be accurately used to reproduce the large dynamic behavior of GaN transistors. The model is organized as follows: Section II describes the theoretical impact of traps on the average current obtained under pulsed load conditions. Section III presents the measurements performed in an ALPHACOM S100 and the results obtained. Section IV presents the model parameters determination and the results obtained. Section V presents the discussion of the model parameters determination and the results obtained. Section VI presents the discussion of the model parameters determination and the results obtained. Section VII presents the discussion of the model parameters determination and the results obtained.
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Introduction

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