NON-LINEAR DISTORTION ANALYSIS OF Ka BAND MMIC's UNDER SINGLE-TONE, TWO-TONE AND NPR EXCITATIONS.

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Abstract:

An experimental comparative study of nonlinear distortion effects in 26-40 GHz frequency band on telecommunication MMIC's subject to constant wave single-tone, two-tone and NPR excitations are presented in this paper. The study is performed using a wave-guide based power measurement setup previously developed and recently fully automated to allow very accurate analyses about nonlinear behaviour of PHEMT SSPA's. The purpose of these studies is to determine the MMIC linearity performances at 29 GHz versus bias conditions. But also to improve the PHEMT technological parameters and the circuits designs as a function of the analyses.

INTRODUCTION

Due to the increasing demand since ten years for mobile and satellite communication systems, it is becoming a key problem, for designers, to have a clear understanding of how nonlinear distortions affect devices and related power amplifiers under multiple carriers and/or finite bandwidth complex modulation excitations.

For that purpose we have developed in our Laboratory a versatile measurement setup **(1).** This one is able, thanks to quick changes of input source, to perform successively single-tone, two-tone and NPR constant wave excitations, associated with analyses. As previously described **(2)**, this setup is mainly devoted to Ka band but can be extended to other bands. It allows power and spectral measurements of connectorized or on-wafer devices. For this latter configuration, the setup is associated with a vector network analyser and an adjustable passive load-impedance.

The present study has been carried out with the MMIC CHA 5296 power amplifier. That circuit was manufactured by United Monolithic Semiconductors (UMS) with 0.25µm gate length PHEMT's. The operating frequency is 29 GHz.

MEASUREMENT SETUP IMPROVEMENTS

Compared to the initial version (**2**), and especially for the two-tone and NPR tests, the measurement setup has been widely improved in terms of power handling capability, dynamics, repeatability and accuracy. First, thanks to an optimized architecture benefiting, for the preamplifier section, from the continuous progresses of commercial MMIC's in noise-factor and linearity. Secondly, thanks to the implementation of a fully automated bias, power monitoring and data acquisition using the Labview software (figure 1).
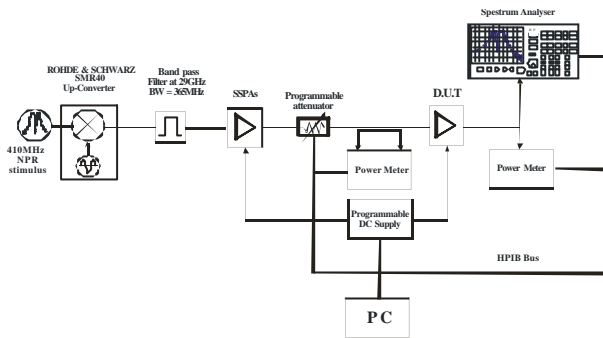
Figure1: The present architecture of the 29GHz NPR measurement set-up.

At present, the measurement system performances at the input plane of the connectorized MMIC's are at 29 GHz:

+ 20 dBm input power capability under single-tone excitation,

+ 15 dBm input power capability with 65 dBc dynamic range under two-tone excitation and a frequency distance of 1MHz

+ 10 dBm input power capability with 47 dBc dynamic range under NPR excitation. The NPR stimulus characteristics are 10 MHz noise bandwidth and 1.5 MHz notch.

MEASUREMENT RESULTS

The CHA 5296 circuit under test is a 27-30 GHz three stages PHEMT based power amplifier. Several variants of DC feed connection are available on the chip, giving us the possibility to optimize self biasing effects on the linearity behaviour. Four bias points have been tested with the following drain voltage and current supplies: 4V-1000mA, 4V-800mA, 5V-800mA and 6V-800mA.

Preliminary tests performed under single-tone excitation (figure 2) let us predict that a strong enhancement of both power and linearity can be expected from the increase of the supply voltage with keeping the drain current at 800mA.
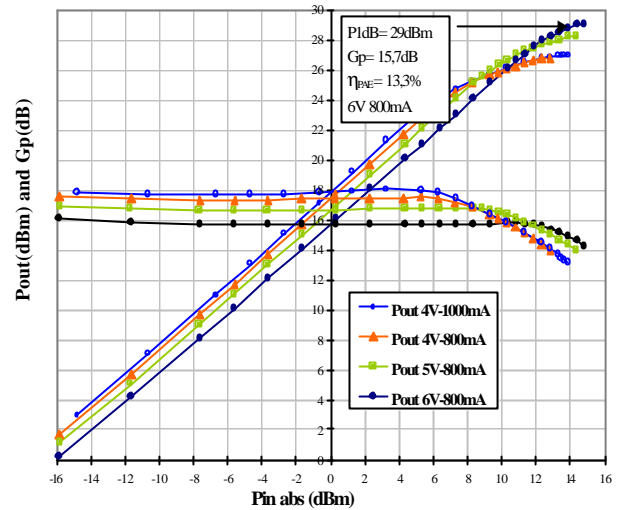

Figure 2: Output power (Pout) versus input power (Pin) for the single-tone excitation and several bias conditions.

In particular, with 6V-800mA, up to 29 dBm CW output power is obtained at 1dB compression, the linear power gain being still of about 16 dB, which is a very high performance considering the present operating frequency of 29 GHz.

Under two-tone and NPR excitations variations of power responses versus bias conditions (figure 3) are very close to the single-tone excitation. Except that, due to the well known non constant waveform envelope effects, the compression occurs earlier and, consequently, the output power capability is lowered (3).
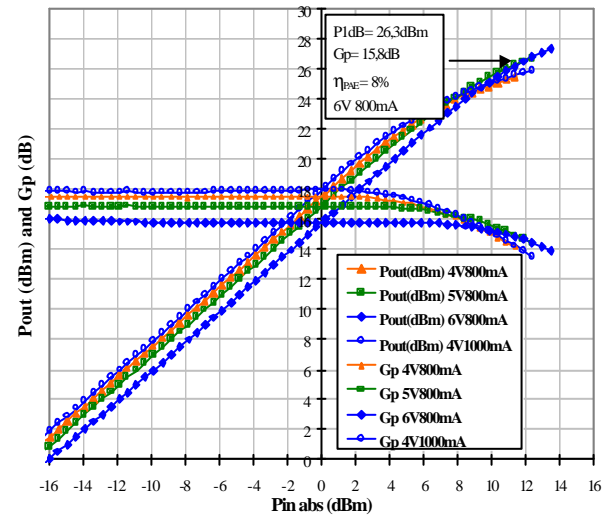

Figure 3: Output power (Pout) versus input power (Pin) for the NPR excitation under several bias conditions

For each measuring variation sequences of the average drain supply current versus power level reveal how excursion is either bottom or top clipped, depending on the quiescent conditions (figure 4).
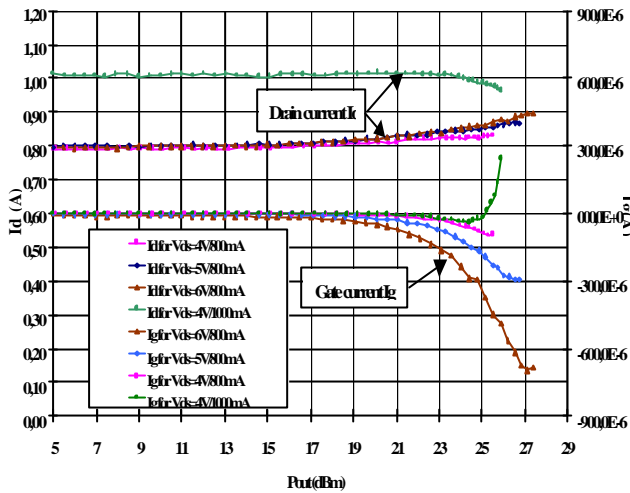
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Figure4: Average drain and gate currents for the NPR excitation under several bias conditions

But, in each case, the average gate current (figure 4) starts reverse biased then switches to forward biasing at ultimate power levels. To avoid damage of the circuit the measurements are automatically stopped as soon as the absolute value of the average gate current reaches the critical value of 1 mA / mm.

Under two-tone excitation IMR_3 (2) measurements versus output power indicate that a substantial improvement is obtained by increasing the drain supply voltage from 4 to 5V then from 5 to 6V, while keeping at 800mA the quiescent drain supply current (figure 5).
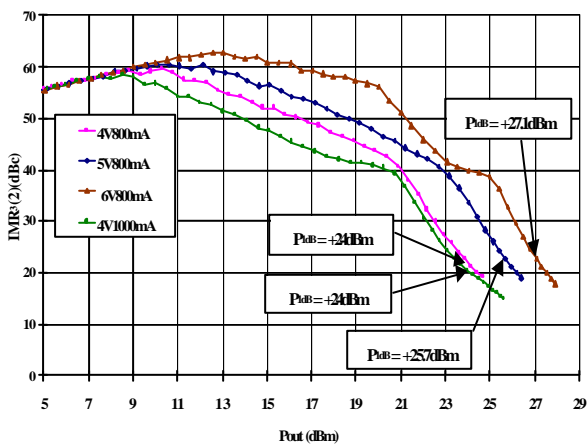

Figure5: IMR_3 behaviour at 29 GHz of the MMIC under several bias conditions

So, at 6V-800mA, IMR_3(2) remains greater than 40 dBc up to 24 dBm CW output power, that is 3 dB

below the 1 dB compression point (referred to two-tone excitation). It can be noted that, due to the predominance of the third order component over the fifth and seventh ones in the IMR spectrum, IMR_3 (2) is then very close to IMR total. It is also to be noted that, under these operating conditions, the circuit is driven under weak class AB, as shown by the variations of the average drain and gate supply currents versus output power (figure 4) for the NPR excitation.

NPR measurements (figure 6) exhibit very similar trends and evolutions versus CW output power and biasing conditions to that of two-tone excitation.
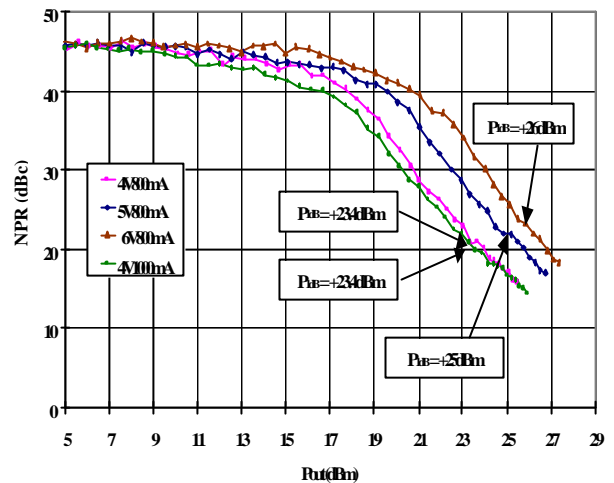

Figure6: NPR behaviour at 29 GHz of the MMIC under several bias conditions

But, as expected, NPR results are somewhat lower than that of IMR_3 (2) at a given output power. Nevertheless, performances are still very good. For instance, at 6V-800mA, NPR remains greater than 35 dBc up to 24 dBm output power, that is only 2 dB below the 1 dB compression point (referred to NPR excitation).

CONCLUSION

Results presented in this paper confirm trends we have previously found in Ka band, at 26 GHz instead of 29 GHz, with other MMIC's. These behaviours have been also observed with discrete PHEMT's. All of them fabricated with the same 0.25μm gate length basic process. Characteristics of IMR_3 (2) and NPR shown here that very interesting performances, both in power and linearity conditions, can be obtained thanks to an adequate design optimization with this versatile PHEMT technology, even nearby 30 GHz.

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