MULTI-TONE TRANSISTOR CHARACTERIZATION FOR INTERMODULATION AND DISTORTION ANALYSIS

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ABSTRACT

This paper presents an experimental study of the effect of different multi-tone excitations on the intermodulation rejection (IMR) of GaAs MESFETs. The IMR parameter is very important in transistor linearity investigation. The objective of this work is to determine the input power backoff required for MESFET operation to provide the same IMR for different tone-number excitations, and the IMR degradation as the number of tones increases at a specific transistor loading. For this purpose, 2, 4, 8, 16 and 32 tones with 100 KHz spacing were applied at the input the transistor under test and its IMR was calculated for an input power sweep and a given loading. The results show that, there is a certain back-off input power level with which the IMR is identical for the different excitation conditions. This work experimentally validate the theoretical one published in the literature.

I INTRODUCTION

Intermodulation distortion (IMD) analysis is a good way to investigate some non-linear behaviors in microwave and millimeter-wave amplifiers and oscillators [1], [2]. It is an important parameter that would provide indication about the linearity of transistors. The IMD analysis is relatively well investigated, theoretically and experimentally, under two-tone excitation [2]-[4]. This was performed on either bipolar or field effect transistors, and good results were obtained for equally leveled tone inputs. However, the intermodulation distortion characterization and analysis under N (N >2) tone equally leveled (or non-equally leveled) excitations is not yet well investigated [5] . A theoretical work on intermodulation distortion in a multi-signal environment were reported in [6] and [7]. In these references equations were provided to calculate the intermodulation rejection (IMR) and the intercept point levels for different situations, but no experimental validation to those equations were performed to complete the work.

One objective of this paper is then to provide an experimental validation of the theoretical intermodulation analysis and an idea about the required power backoff to maintain a constant intermodulation rejection (IMR) for excitations having different number of tones. An other objective of this work is to validate experimentally , the degradation of the IMR as the number of tones increases. To accomplish such objectives, an experimental set up is developed and can be used to perform load-pull measurements in multi-tone environment. Thus, one can optimize the IMR of a certain transistor with an optimal loading.

II DESCRIPTION OF THE MEASUREMENT SET UP

To perform load-pull measurements in a multi-signal environment, it is important to firstly generate a very clean multi-tone signal (2, 4, 8, 16, 32, 64, ...tones) to be driven to the input of the transistor. This is performed by using an Arbitrary Wave Generator (AWG), an RF source and a simple mixer. The whole measurement system is shown in Figure 1. With the AWG, we fix the number of tones, the carrier spacing and the tone level. The two inputs of the mixer are then connected to the AWG and the RF source, respectively. At the output of the mixer, a narrow band and selective filter is inserted to pass only the desired clean tones which should be applied to the input of the transistor. With such configuration, one can generate a large number of multi-tone signals with an initial IMR of 55 dBc. The obtained clean multi-tone signal is then driven to a linear amplifier to increase the signal power level. This is done because the output signal of the mixer has very low level. The resulting multi-tone signal is finally driven to the input of the transistor.

The power and reflection coefficient measurements were performed by using the Microwave Transition Analyzer (MTA HP 70820). This instrument is used to measure the incident and the reflected signals at each port of the device under test which are sampled by two dual directional couplers. The four sampled signals (2 at the input and 2 at the output) are selected by a switching stage (see Fig. 1). At the output of the transistor, a mechanical tuner is used to vary the transistor loading for load-pull measurement purposes.

The system is controlled by a PC computer and the data acquisition is done via HP-IB Bus. The HP-Vee-Test software was used to develop the instrument control program

III EXPERIMENTAL RESULTS

The characterized transistor is a MESFET (ACK0151P) having a 1-dB compression point at $P_{1dB}=20\ dBm$. The MESFET was biased at $V_{ds}=10\ V$ and $I_{ds}=100\ mA$ for class A operation. The measurements were carried out for input signals having 2, 4, 8, 16 and 32 tones. Load-pull measurements were made to determine the optimum load for maximum output power. This load was found to correspond to $\Gamma_L = 0.58 < 172^o$. Using the MTA, we measured: the input reflection coefficient; the absorbed input power per tone; the output reflection coefficient; the output power per tone and the third order Intermodulation Rejection (IMR) of the transistor. For each number of tones, the IMR parameter were measured for an input power sweep up to the 1-dB

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compression region of the transistor. Such measurement were repeated for 10 random phase distributions of the tones. The experimental results presented here correspond to the two extreme cases of the phase distribution among the 10 cases considered.

Figure 2 shows the theoretical (reported in ref. [7]) and the measured IMR degradation as function of the number of tones for a constant input power level per tone ($P_{in/tone}=4\ dBm$) . One can see that there is an acceptable agreement between the measurements and the theory, and the theoretical IMR degradation falls in the range of the two extreme phase distribution cases.. The deviation observed is due to the fact that the theoretical curve reported in [7] is an average of many curves corresponding to different phase distributions of the tones. Figure 3 illustrates a comparison between the measured IMR degradation as function of the number of tones for an identical total input power ($P_{in-total}=7\ dBm$) of the different number of tones and the theoretical results [7]. The total input power is deduced by using equation (1). Again, the theoretical IMR degradation falls in the range defined by the two extreme phase distributions of tones.

$$P_{in/total} = P_{in/tone} + 10 \times \log(N) \qquad (1)$$

where N is the number of tones.

From Figures. 2 and 3, it can be concluded that the phase distribution of the carriers has a strong influence on the transistor IMR. It is shown that there is a maximum difference of 15 to 20 dBc between the IMR degradation values of the two presented phase distribution cases.

Figure 4 shows the measured and theoretical [7] total input power backoff required to maintain a constant IMR. The theoretical results fall again in the range bounded by the two presented phase distribution cases. It is also important to notice that for a certain phase distribution of the carriers, total input power backoff is not needed to maintain a constant IMR. This is illustrated in Figure 4, for a given random phase distribution, the power backoff required is very small, around 0.2 to 0.4 dB.

IV CONCLUSION

In this paper we presented an experimental multi-tone characterization of a microwave GaAs MESFET. One of the purposes of this work is to validate the theoretical results reported in the literature regarding the degradation of intermodulation rejection as the number of tones increases as well as the total input power backoff required to maintain a constant IMR as the number of tone increases. The experimental IMR results we obtained are in an acceptable agreement with the theoretical results. A considerable effort has been made to develop the automated multi-tone measurement set up. This was achieved by using an Arbitrary Waveform Generator and a Microwave Transition Analyzer. The ongoing work using this system concerns multi-tone load-pull characterization of transistors with different phase distribution of tones and different classes of operation of the transistor.

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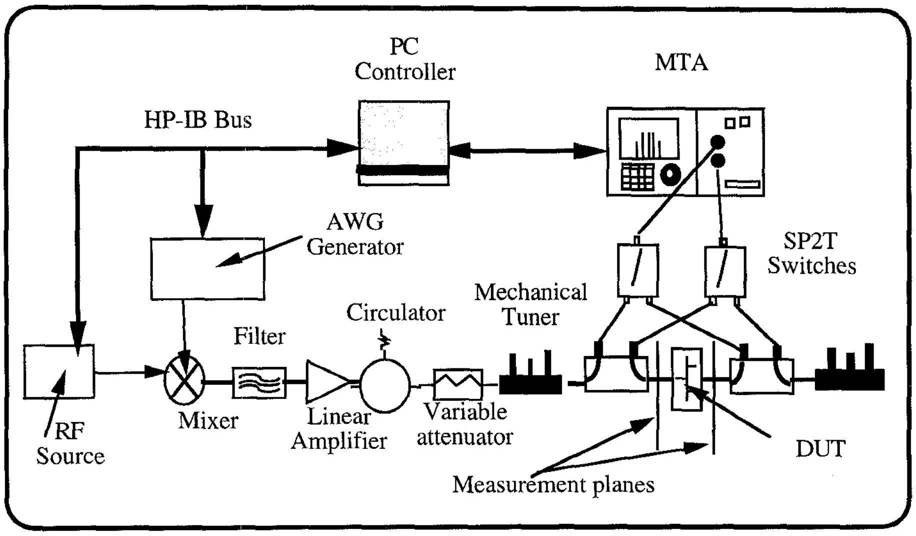

Figure 1: Multi-tone load-pull mesurement set up

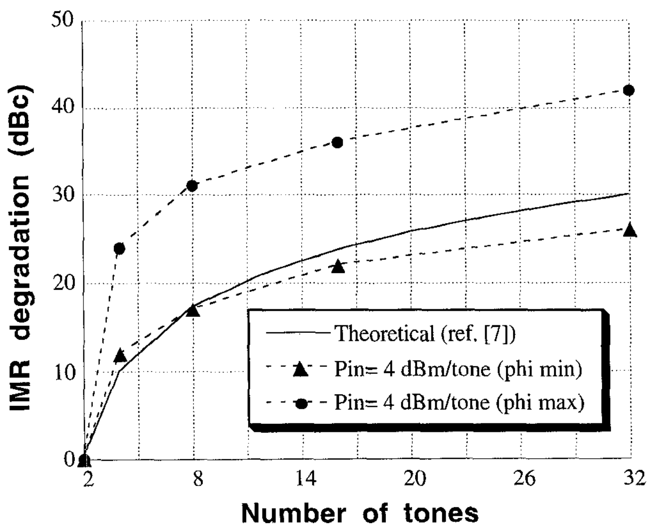

Figure 2: IMR degradation with constant input power per tone

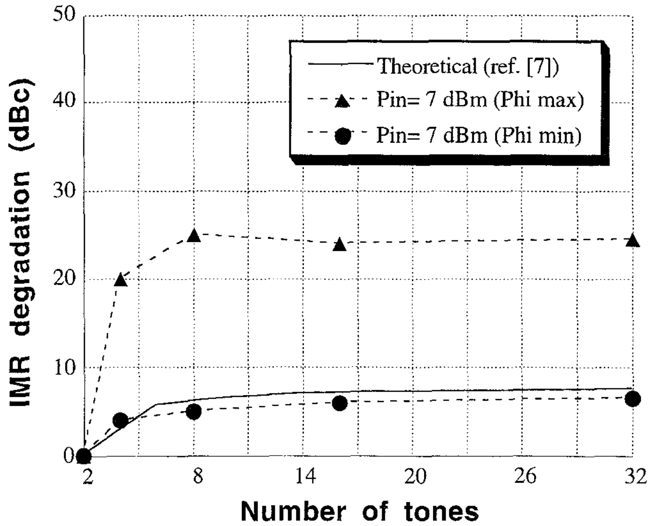

Figure 3: IMR degradation with constant total input power

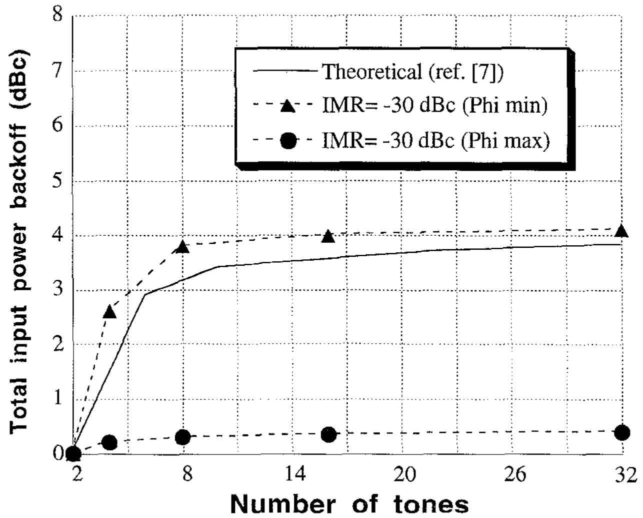

Figure 4: Required power backoff to maintain constant IMR