The role of correct Measurements in the Modeling of Microwave Active Devices

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Abstract — This paper describes some of the experiences and know-how of our group in the measurement of microwave active devices, namely MESFETs, HEMTs and HBTs transistors, as well as the development of electrical models based on such measurements. The aim of this work is to popularize in the scientific community some improvements in the measuring techniques, in order to get more accurate electrical models, particularly in medium and high power devices.

1. Introduction

An important relationship exists between the models of active microwave devices, the techniques of parameter extraction and their measurement. Accuracy and precision of these techniques contribute directly to the correct behavior of the model, even for models based in the physical properties of the semiconductor that require information on the geometry and characteristic of the materials of the device.

The gate-width and the doping profile are examples of parameters typically used in a physical model. In order to develop an electrical or electro-optical model of a microwave transistor, it is an indispensable condition to proceed to measure the device with the maximum possible precision and in an automatic way. These measurements will be used as starting point in the automatic extracting tools developed and designed by different authors [1-4] for such purpose in different laboratories. For this reason, a description of some of the refinements in the measurements are described here, such the use of a sensing system to take into account the resistance of the wires used to bias the transistor.

2. DC Measurements

A frequent error at the time of performing the characteristic DC curves measurements of medium and high power microwave transistors, is not to take into account the voltage drop in the wires used for biasing the device due to their resistance. For medium power devices a voltage drop of several tenths of volt can be developed because of the high currents through the feeding wires. These voltage differences are very important, mainly in the linear region of the transistor, since the slope of drain current for FET devices or collector current for bipolar devices, do not reach the “real” voltage level that the DC source indicates. As a consequence of this, some “false” DC curves can result, as shown in figure 1, for a medium power MESFET device of 10 by 140µm of gate periphery, manufactured by GEC-Marconi.

In order to avoid the addition of this series parasitic resistance, the DC source should incorporate a sensing system to sample the actual voltage applied to bias the transistor at the connection point to the wire.

Figure 1. I-V characteristics “True Curves” and “False Curves” for a medium power MESFET transistor 10*140µm of gate with from GEC-Marconi.
If it is not possible to use a DC source with such sensing capability, a possible solution is to control this effect by measuring the voltage at the bias connection point by means of a programmable digital multimeter, and to compare this voltage with that at the output of the DC source. If the difference between them is significant, it is possible to use some kind of software that control the DC source and multimeter to increase the output voltage of the source in order to obtain the correct reading in the multimeter.


In many cases, the internal bias-tee provided with the VNA has been used when multibias scattering measurements are performed. This is another added handicap in the correct measurement of DC and scattering simultaneously. Another improvement presented here is the use of an external bias-tee, with sensing capability for the proper bias of the device. The use of the internal bias-tee of a network analyzer usually exhibits a non-linear resistance that is a function of the internal temperature of the VNA as well as other external factors such as room temperature. In our case, we proceeded to measure this internal resistance using a 4-wire digital multimeter under different conditions. The mean value obtained was 3.8 Ohm for a VNA model HP8510 from Agilent. If the device under test is a low power one, the differences in using the internal or external bias-tee can be neglected, but for medium and high power devices (more than 0.5A of drain or collector current), this additional resistance must be removed, either by using the aforementioned technique, or by means of a software routine during the automated measurements, in order to properly measure the device. Another source of systematic measurement errors is the ohmic resistance introduced by the tips of the probes used to measure active on-wafer discrete devices and MMICs. From an RF point of view, this effect has been taken into account in the calibration procedure, but from the DC point of view, this effect has been removed by the TRL discrete devices and MMICs. From an RF point of view the probes used to measure active on-wafer errors is the ohmic resistance introduced by the tips of the probes used to measure active on-wafer errors.

Another added handicap in the correct measurement of DC and scattering simultaneously is the difference in using the internal bias-tee of a network analyzer usually exhibits a non-linear resistance that is a function of the internal temperature of the VNA as well as other external factors such as room temperature. In our case, we proceeded to measure this internal resistance using a 4-wire digital multimeter under different conditions. The mean value obtained was 3.8 Ohm for a VNA model HP8510 from Agilent. If the device under test is a low power one, the differences in using the internal or external bias-tee can be neglected, but for medium and high power devices (more than 0.5A of drain or collector current), this additional resistance must be removed, either by using the aforementioned technique, or by means of a software routine during the automated measurements, in order to properly measure the device. Another source of systematic measurement errors is the ohmic resistance introduced by the tips of the probes used to measure active on-wafer discrete devices and MMICs. From an RF point of view, this effect has been taken into account in the calibration procedure, but from the DC point of view, this value has been taken into account in the measurement procedure, for medium and high power devices (a typical value of 0.25Ω is usual for different manufacturers of microwave probes).

Finally, there is a systematic error that appears when on-wafer measurements, caused by the effect of the ambient illumination over the chip. This effect is easily taken into account when the laboratory where measurements are performed is under natural or artificial illumination. In the measurement of the I-V characteristics and scattering parameters of a microwave chip transistor, it is necessary to measure it in the nearest possible conditions that approximate their future operation inside a microwave system. Such conditions are usually darkness. An easy solution to avoid this problem is to enclose the probe station in a chamber without illumination. Our group performs the measurements in such a way and a comparison between dark conditions and room illumination is shown in figure 2 for a 2*150 μm MESFET device from GEC-Marconi foundry. In the same figure, a comparison between measurements with laser illumination using the system reported in [5] is shown, for the same device and bias point (Vgs=-1.75 V, Vds=3V), with frequency sweep between 0.5 and 26.5 GHz. It can be said that the effect of ambient illumination is equivalent to that of a laser spot of 2mW of optical power, properly positioned over the fingers of a medium power transistor. Therefore, the effect of ambient illumination must be taken into account in this kind of measurements.

![Figure 2. Comparison of measured scattering parameters in dark conditions, ambient illumination and 2mW of CW laser illumination on a 2*150 μm MESFET device from foundry GEC-Marconi. Vgs=-1.75 V, Vds=3V, frequency sweep 0.5-26.5 GHz.](image-url)

4. Conclusions

When the measure of I-V curves and scattering parameters of a microwave transistor are made, it is necessary to measure them in the nearest conditions resembling their future operation inside a microwave system. The quality and behavior of the model developed from these measurements depends on their accuracy. To avoid some negative effects that mask the measurements, an easy set of solutions has been proposed.
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References:


