LOW FREQUENCY DISPERSION EFFECTS ON THE INPUT CHARACTERISTICS OF MICROWAVE FETs

Vicentiu I. Cojocaru and Thomas J. Brazil

Department of Electronic and Electrical Engineering
University College Dublin, Dublin 4, Ireland.
Tel: +353-1-7061912; Fax: +353-1-2830921; Email: vivi@hertz.ucd.ie

ABSTRACT

The paper presents the experimental results of a low frequency test carried on a packaged GaAs MESFET, emphasizing the presence of some significant dispersion effects in relation to the input C-V and I-V characteristics of the device. The test has been performed within the frequency range 10kHz÷40MHz on a commercial, packaged GaAs MESFET, connected in a special configuration and using an impedance meter system. The results presented show a significant variation of these two input characteristics with frequency.

INTRODUCTION

The discussions around the low-frequency dispersion phenomena in microwave FETs tend to concentrate around their effects on the transconductance and on the output conductance parameters, mainly because these effects have, by far, the biggest impact on the overall performance of the device, and implicitly on that of the device models. However, the presence of electron traps, surface charges and/or thermal drift phenomena inside the device, are in reality very likely to affect as well, to a larger or lesser extent, some of the other parameters that are part of a typical microwave FET model. Apart from some early reports on such effects on the gate capacitance [1][2][3], there haven't been many reports in literature regarding any observed low-frequency dispersion effects on model elements other than the transconductance and the output conductance [1]-[4].

The relative lack of research in this area is mainly due to the comparatively small impact that low frequency dispersion of the input characteristics has on the overall performance of these devices. For example, at frequencies around *1*MHz, considering typical values for the gate capacitances of the order of *0.5*pF or less, this results in reactance values associated to the capacitance of the order of *200*kΩ or more. This means that if the value of the capacitance increases by *100*% as a result of dispersion effects at low frequencies, its reactance would still be somewhere above *100*kΩ. Such variations, within this range of magnitudes, for the equivalent reactance values are unlikely to affect in any significant way the overall characteristics of the device at these frequencies. Another possible explanation for the apparently limited amount of research on the low frequency dispersion effects on the gate capacitances is to do with the relative difficulties encountered in measuring these effects.

This work presents results of an investigation carried out on the kind of effects mentioned above and based on a measurement technique implemented using an impedance meter system (*HP4194*). This system allowed us to measure the dispersion effects on the total gate capacitance and total gate current within the frequency range *10*MHz÷*40*MHz, for the special case when the external drain and source terminals of a commercial, packaged GaAs MESFET (*NE71083*) are physically connected together (i.e. $V_{DS} = 0$ V at all times).

LOW FREQUENCY DISPERSION OF THE GATE CAPACITANCE

For this particular case (source and drain connected together), we can consider the low frequency, small-signal equivalent circuit model shown in Figure 1, which is based on the typical small-signal model [5] for the "cold FET" situation ($V_{DS} = 0$V). The effect of the parasitic inductances can be ignored at these low frequencies. R_{cho} represents the value of the channel resistance when $V_{DS} = 0$V.

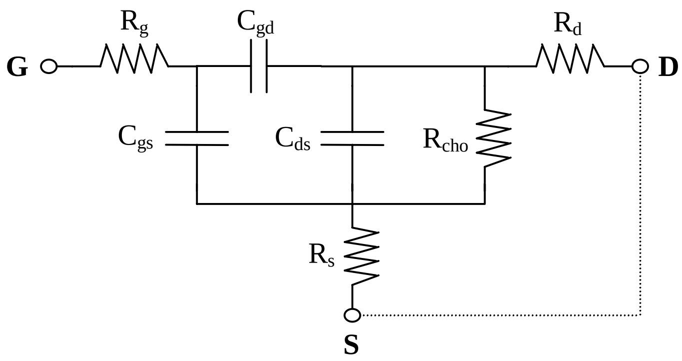


Figure 1 Simplified low-frequency equivalent circuit model of a packaged microwave FET for $V_{DS} = 0$V.

If we consider the situation when the source and the drain terminals are physically connected together, the equivalent circuit could be redrawn as shown in Figure 2.a. Considering the balance between the values of the resistances and reactances in that circuit at frequencies below *1*MHz, the small-signal equivalent circuit model can be further simplified to the level shown in Figure 2.b. In that equivalent circuit C_g represents, with some good approximation, the total gate capacitance. At this point, it is quite obvious that by measuring the *C-V* characteristics between the gate terminal and the source/drain terminal at various low frequencies, we can obtain the information we are looking for with regards to the total gate capacitance of the device.

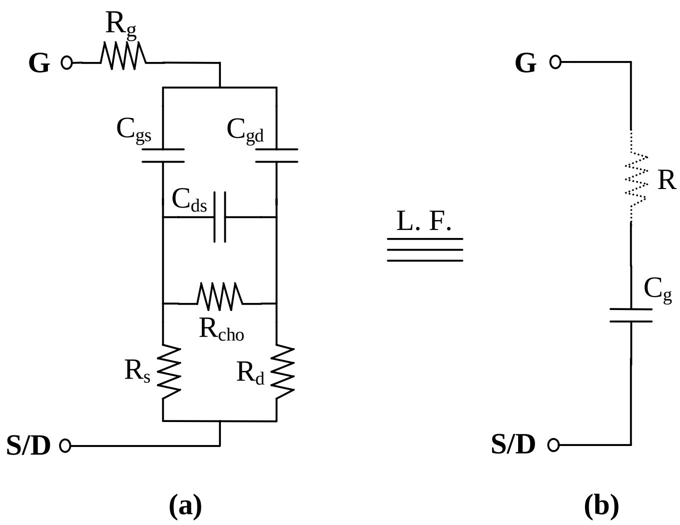
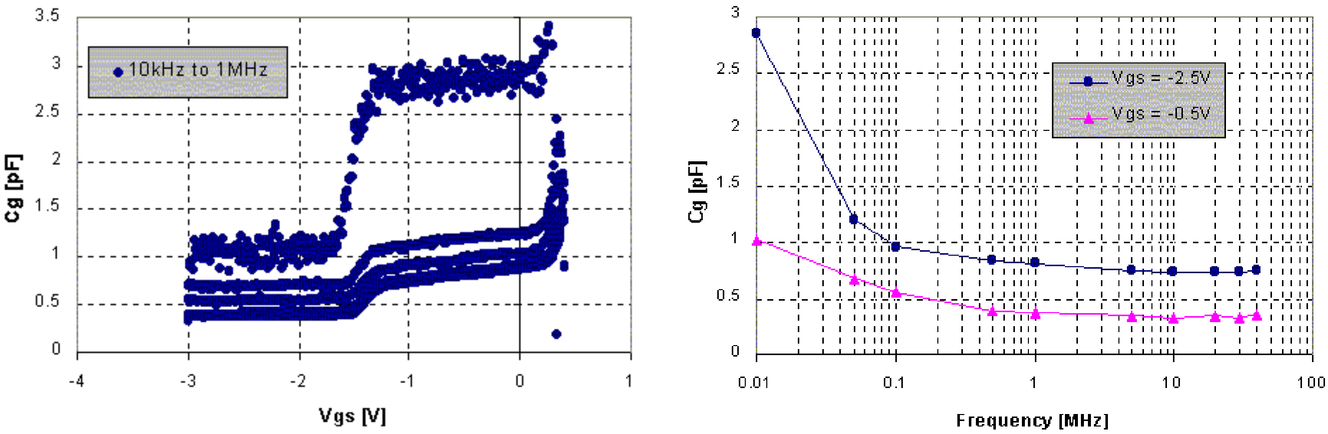


Figure 2 **(a)** Simplified small-signal equivalent circuit model of a packaged microwave FET when the drain and source terminals are connected together; **(b)** Same circuit model further simplified for low-frequency conditions.

We have carried this test on a typical commercial packaged GaAs MESFET device (*NE71083*, with a pinch-off voltage around -*1.5*V). The test frequency has been swept between *10*kHz and *40*MHz. For practical reasons we could not expand this test below 10 kHz. At each frequency, the total gate capacitance (C_g) has been measured over the full V_{gs} range, from well below pinch-off, to the forward bias region. The results of the test are quite revealing and confirm the impact that low frequency dispersion phenomena have on the total gate capacitance value. Figure 3.a shows the *C(V)* dependency as determined for a few different test frequencies (*10*kHz, *50*kHz, *100*kHz, *500*kHz, *1*MHz). Alternatively, in Figure 3.b, we show the frequency dependency of the total gate capacitance at two different bias voltages situated below (V_{gs} = -*2.5*V) and above the pinch-off (V_{gs} = -*0.5*V), respectively. For this particular device, a sharp decrease (of up to *200*%) in the value of the total gate capacitance is observed to take place between *10* kHz and *50* kHz, in the region where the channel begins to open. This kind of behavior is in agreement with that found in [2].



(a) **(b)**

Figure 3 **(a)** *C-V* characteristics for a packaged GaAs MESFET (*NE71083*) measured at five different frequencies (10kHz, 50kHz, 100kHz, 500kHz, 1MHz), for the case when the drain and source terminals are connected together ($V_{DS} = 0$V); **(b)** $C_g(\omega)$ characteristics for the same device measured at two different gate-to-source voltages ($V_{GS} = -2.5$V and $V_{GS} = -0.5$V).

LOW FREQUENCY DISPERSION OF THE INPUT *I-V* CHARACTERISTICS

In parallel with the $C(\omega)$ characteristics, the low-frequency test described in the previous section can also provide us with some information regarding the input *I-V* characteristics of the GaAs MESFET device. Of course, this information, corresponds to the same special device configuration, when the drain and source terminals are physically connected together. Following from the simplified circuit model seen in Figure 2, the equivalent large-signal model of the microwave FET at low frequencies is shown in Figure 4.

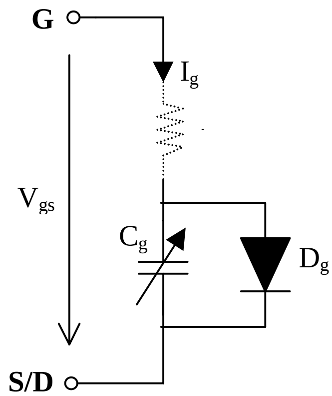
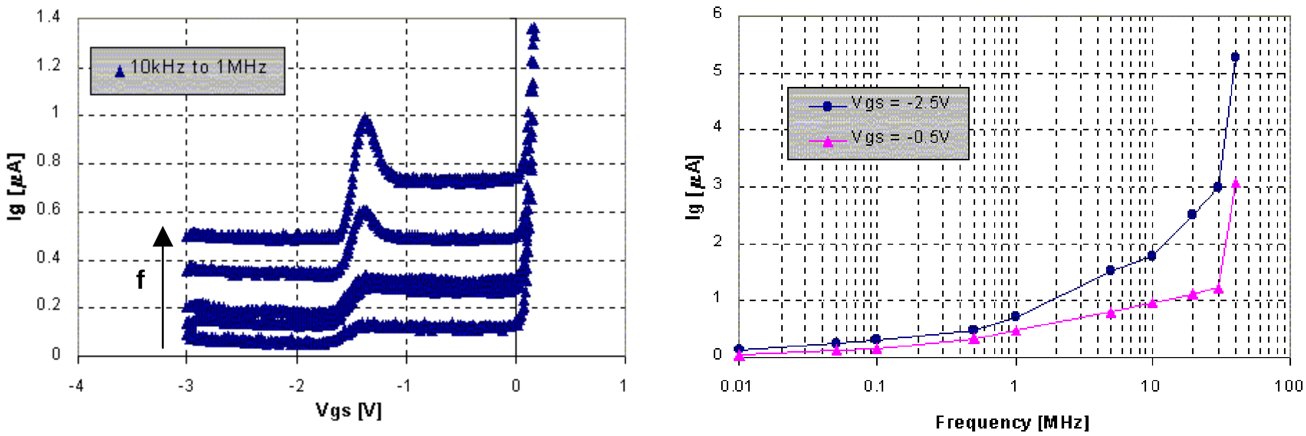


Figure 4 Simplified large-signal, low-frequency equivalent circuit model of a packaged microwave FET when the drain and source terminals are connected together.

So far, there have been no reports in literature regarding any observed dispersion effects on the input conductance of microwave FETs. The measurement setup used in our case cannot provide us with direct information about the value of the FET's input conductance, but it can provide information on the frequency variation of the total gate current, I_g (considering the special circuit configuration employed). We consider the same test as previously, performed on a commercial packaged GaAs MESFET (*NE71083*, with a pinch-off voltage around -*1.5*V). Again, the test frequency has been swept between *10*kHz and *40*MHz. At each frequency, the total gate current (I_g) has been measured (in parallel with C_g) over the full V_{gs} range, from well below pinch-off, to the forward bias region.

The results of the test reveal that the dispersion phenomena have also an impact on the value of the total gate current. Figure 5.a shows the $I_g(V_{GS})$ dependency for a few different test frequencies (*10*kHz, *50*kHz, *100*kHz, *500*kHz, *1*MHz). Alternatively, in Figure 5.b we show the frequency dependency of the total gate current at two different bias voltages situated below (V_{gs} = *-2.5*V) and above the pinch-off (V_{gs} = *-0.5*V), respectively. The total gate current is seen to follow an increasing trend from low frequencies towards high frequencies, with a significant increase taking place when we move to frequencies beyond *1-10*MHz. The highest frequency where the measurement has been performed was again *40*MHz. Towards the higher frequency range, any accurate measurement of the $I_g(V_{GS})$ characteristics is likely to become more difficult to perform due to the influence of a comparable (decreasing) reactance of the gate capacitance.



(a) **(b)**

Figure 5. (a) The input *I-V* characteristics for a packaged GaAs MESFET (*NE71083*) measured at low frequencies (from 10kHz to 40MHz), for the case when the drain and source terminals are connected together (V_{DS} = *0*V); **(b)** $I_g(\omega)$ characteristics for the same device measured at two different gate-to-source voltages (V_{GS} = *-2.5*V and V_{GS} = *-0.5*V).

CONCLUSIONS

We have presented the results of an investigation on the low frequency dispersion effects on the total gate capacitance and total gate current characteristics of a GaAs MESFET device. They show that these parameters can exhibit some significant variations in the low frequency range. The results and conclusions presented in this paper should however, be looked at with due caution, since they are based on a limited number of very sensitive experimental tests. Also, it is not clear from these tests what is the interdependence between the dispersion effects on the C_g and I_g characteristics. A more appropriate analysis of the dispersion effects on the gate characteristics is difficult to perform, mainly because low-frequency measurements on FET devices operated in normal conditions ($V_{DS} \neq 0$V) is a very challenging task.

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