Influence of recess and epilayers in the 26 – 40 GHz band HEMT's intermodulation

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ABSTRACT

The comparison of the linearity performance for three PHEMTs have been investigated in Ka band. The studied transistors are a single recessed PHEMT, a double recessed PHEMT and a double recessed dual channel PHEMT. The main result is : at a given output power level, the double recess allows a large improvement of the intermodulation ratio (IMR), thanks to its higher drain-source bias voltage capability, compared to the single recess. The second result is : the double recessed PHEMTs comparison shows that the dual channel, thanks to a more wide and uniform transconductance distribution than the single channel, is a better solution for linearity application at 26GHz.

INTRODUCTION

With the development of local multipoint distribution (LMDS) there is now considerable activity in Ka band. Communication services, such as television, video on demand, distance learning, INTERNET access... are at the basis of this one. This tremendous need has created considerable interest in the development of Ka band power amplifiers [1]. As a consequence the linearity behaviour, in terms of third and fifth order intermodulation (IM3, IM5) and intermodulation ratio (IMR), needs to be correlated with the main device process parameters.

TEST SYSTEM DESCRIPTION

The test system is composed of two synthesisers and two SSPA in order to generate and to amplify the excitation signals. These combined signals are injected in the input probe of the device. Powermeters measure the injected and absorbed powers at the device input and the output load. A vector network analyser is used to measure the DUT S'11 and the output load impedance. A special output probe is used in order to reduce losses between the tuner and the device output. A detailed description of this setup has been already described elsewhere [1]. In all the paper the operating frequency is 26GHz and the two-tone measurements are carried out with a 1MHz spacing.

DEVICES DESCRIPTION

The single channel PHEMTs have been achieved on GaAs substrate, with delta doping, and exhibit a drain current density at open channel (Vgs=0.8V) around 600mA/mm. The 0.25µm gate is centred in the drain source spacing and in the recess. The gate width is 2x75µm. For the single recessed device (PH25) the distance between the gate edge of the cap layer, usually named "ungated recess", is of about 30nm. The double recessed device (PPH25) has the same narrow gate recess as the previous device but with in addition a second wide recess of 1000nm centred on the gate. The double recessed dual channel device (top : GaAs, bottom: InGaAs) PHEMT (981209) is achieved on GaAs substrate and exhibits a drain current density at open channel around 850mA/mm (Vgs=0.8V). The 0.2µm gate is centred in the drain-source spacing and in the recess. The gate width is 2x50µm. The ungated recess is of about 35nm. The second wide recess of 1000nm is centred on the gate. Hence for the double recessed devices the topologies are almost identical.

MEASUREMENT RESULTS

Table 1 shows power measurement results under single tone excitation for the three devices at different bias conditions with the optimal power load impedances. The highest output power is provided by the double recessed dual channel device but the best PAE relates to the double recessed single channel device. It is to be noted that the maximum output powers given in table 1 correspond to 3 to 4 dB compression, excepted the case of the 981209 device at 5V where compression is only 1dB. Indeed, due to its very high doping, this device is limited by its breakdown voltage and 670mW/mm is the power level attained at 1mA/mm of gate current.

Then, these devices have been studied with a two-tone excitation. Output power for each tone and the third and fifth order intermodulations are shown in figures 1, 2, and 3 versus the total input power level with the optimal power load impedances. A decrease of the maximum output power is noted between the two excitation modes whatever the devices. This well known behaviour [2] is related to the instantaneous envelope variation which arises from the beat-like two tone signal. Indeed for a same total input power level clipping occurs earlier in the two-tone mode than in the one-tone mode.

An other interesting aspect lies in the various rate of rise exhibited by the 3rd order intermodulation product (IM3) versus the input signal level. Figure 2 shows, for an input power level of –4dBm, a quasi cancellation of the IM3 product. We can notice that the fifth order intermodulation (IM5) power level is equal to the IM3 level for this input power level. This phenomenon is usually interpreted as a contribution of the IM5 product to the IM3 product, when the two contributions are comparable in magnitude and are nearly out of phase (180°). This kind of behaviour is always been noted as soon as the IM5 has the same order of magnitude than the IM3 [1]. The influence of the IM5 increases when the drain-source bias voltage increases. Measurements and analyses on the linearity behaviour will be presented versus the drain source and gate source bias voltages.

Figure 4 shows the IMR level as a function of the total output power level for the three devices (corresponding to figures 1, 2 and 3). First remark : the PH25 has the worst IMR due to its low Vds biasing capability. Nevertheless it can be noted that, for same bias conditions (Vds=3V, Class A), the PH25 is better than the other devices. Second remark : the dual channel double recess is the better solution for power linear application [3] excepted at medium power level (4.5 to 8dBm) where the PPH25 is momentarily superior.

CONCLUSIONS

This study has shown all the interest of the double-recessed structure for linear power application at 26GHz. On the other hand, the comparison between the single channel and dual channel HEMTs indicates the superiority of the former in terms of PAE and the superiority of the latter in terms of output power level and, more particularly, in terms of IMR.

REFERENCES

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[3] Feng-Tso Chien, Shien-Chin Chiol, Yi-Jen Chan, “Microwave Power Performance Comparison Between Single and Dual Doped-Channel Design in AlGaAs/InGaAs HFET’s”, IEEE Electron Device Letters, Vol. 21, No 2, pp 60-62, February 2000.

	Drain-source voltage / Class of operation	Linear Gain	Maximum output power	Power added efficiency
PH25	3V / A	11.6 dB	420mW/mm	41%
PPH25	3V / A	11.2 dB	340mW/mm	45%
PPH25	5V / A	10.5 dB	550mW/mm	32%
981209	3V / A	9.6 dB	520mW/mm	32%
981209	5V / A	9 dB	670mW/mm	20%

Table 1 - power measurement results under single tone excitation for the three devices at different bias conditions with the load impedance optimised for maximum output power.

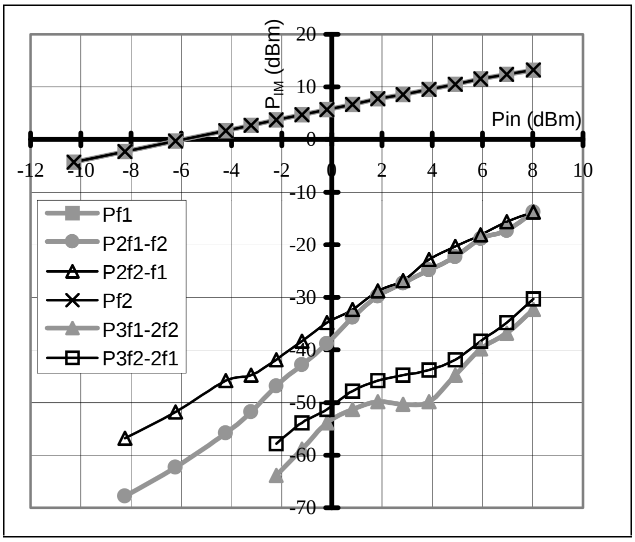

Figure 1 – 981209 output power for each tone and output power for 3rd and 5th IM versus total input power level for two-tone excitation (Vds=5V Class A)

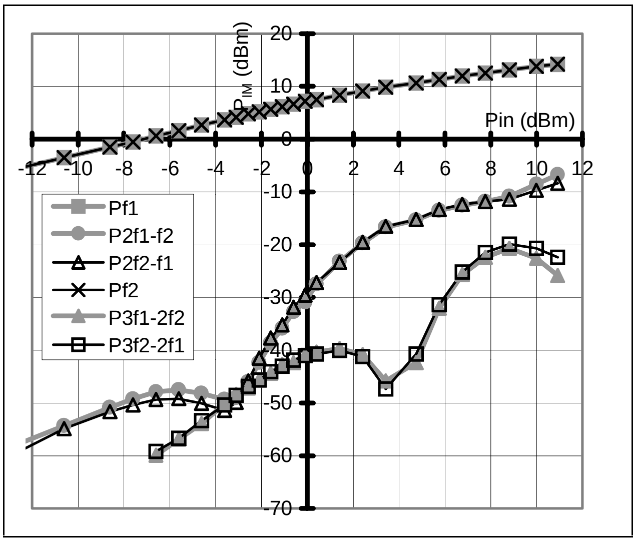

Figure 2 - PPH25 output power for each tone and output power for 3rd and 5th IM versus total input power level for two-tone excitation (Vds=5V Class A)

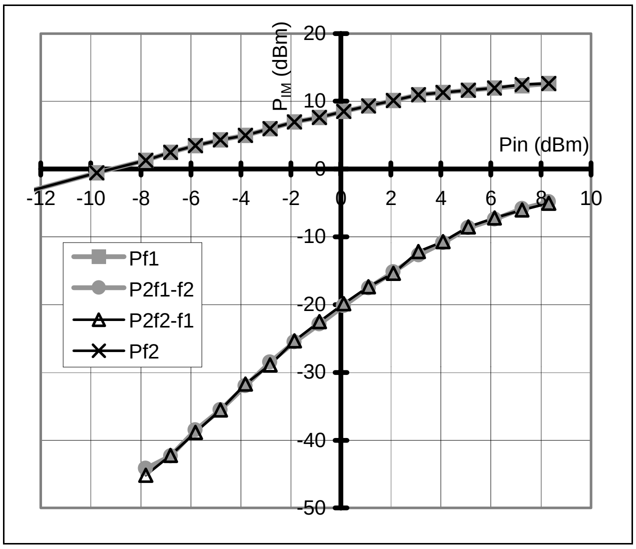

Figure 3 - PH25 output power for each tone and output power for 3rd IM versus total input power level for two-tone excitation (Vds=3V Class A)

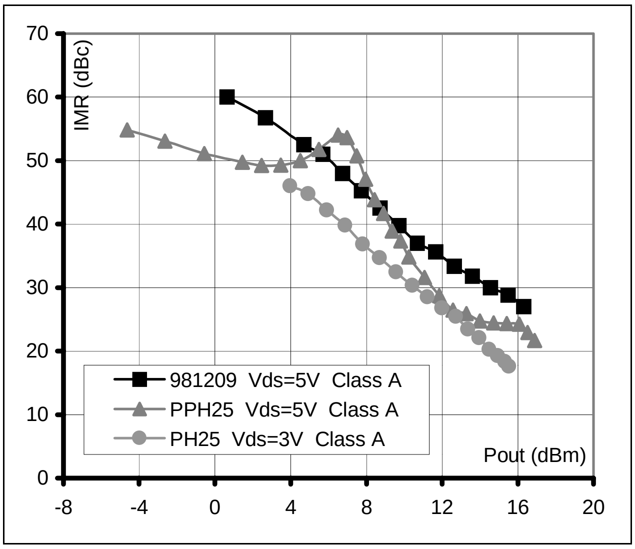

Figure 4 - IMR level as a function of the total output power level for the three devices (corresponding to figures 1, 2 and 3).