MICROWAVE NOISE FIGURE IN MESFETs and HEMTs with KINK-EFFECT and (or) PARALLEL CONDUCTION

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ABSTRACT

This paper considers the influence, on the microwave noise figure, of the kink effect often noticed in MESFETs and HEMTs and then of parallel conduction sometimes observed in HEMTs.

It is found that kink effect impacts mostly on MESFET noise and that parallel conduction impacts on HEMT noise especially when operated at large drain current. Consequences on optimal bias conditions for low noise amplifiers are outlined.

I. INTRODUCCION

Gallium Arsenide Field Effect Transistors (MESFET, HEMT, and pseudomorphic HEMTs referred to as PHEMTs) are now extensively used at microwave and millimeter-wave frequencies for lownoise applications. Moreover parasitic effects in the DC characteristics (output current I_{DS}, output conductance G_{DS} and transconductance G_m) occur under certain bias conditions.

MESFETs and HEMTs when biased at a given drain-source voltage V_{DS} (usually beyound 2 V) exhibit in their output characteristic I_{DS} (V_{DS}, V_{GS}) a kink effect which appears as a sudden increase of DC output conductance G_{DS}.

In Modulation Doped FETs and at a given drain bias, the transconductance often peaks at a gate-source voltage V_{GS1} different from zero volt. Indeed beyond V_{GS1} the drain current partly flows through the doped GaAlAs layer where the carriers experience a low mobility which translates into a G_m reduction. This phenomenon is therefore called "parallel conduction" or "parasitic MESFET" [1].

The present paper reviews the influence of these parasitic effects on the minimum noise figure at microwave frequencies (18 GHz) observed during experimental investigations conducted on commercially available GaAs FETs.

IMPACT of KINK-EFFECT on MICROWAVE NOISE PERFORMANCE of HEMTs and MESFETs.

Kink effect has been atributed to impact ionization phenomenon [2] or space-charge-limited current associated with deep traps in the substrate [3]. The origin of this effect has not yet been well established and its influence on microwave noise performance has not been reported yet.

We therefore performed DC and microwave noise parameter characterizations on MESFETs and HEMTs biased in the kink effect region.

a) MESFETs.

FIG. 1a shows the observed variations versus V_{DS} of the output conductance G_{DS} measured at DC (V_{GS}=0 V) for two different MESFETs. They are commercially available device: the first one (NE04583) is referred to as N and features a 0.3x200 um gate area and the second (FSX02 called F) features a 0.5x280 um gate area. The sudden G_{DS} increase observed on device N beyond V_{DS}=2 V denotes the occurrence of the kink effect which is not present within device F.

FIG. 2b plots the minimum noise figure Fmin versus V_{DS} (V_{GS}=0 V) measured at 18 GHz on devices N and F. No significant noise variations versus V_{DS} are observed on device F. On the contrary a sharp Fmin increase occurs on device n beyond V_{DS}=2 V. This substantiates the assumption that some impact ionization is responsible for the kink effect. Indeed impact ionization is associated with an extra multiplication noise and therefore induces a noise figure degradation which

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must be observed beyond a given V_{DS} only on devices featuring some kink effect.

b) HEMTs.

Figs. 2a and 2b plot the G_{DS} and Fmin variations versus V_{DS} observed on two commercially available HEMTs: one is referred to as HM and is a GaAlAs/GaInAs pseudomorphic HEMT (MGF4313 featuring a 0.35x200m um gate area) and the other is a standard GaAlAs/GaAs HEMT (NEC202 fecaturing a 0.3x200 um gate area) known as HN. Fig.2a shows that device HN exhibits a kink effect beyond V_{DS}=2.5 V. Nevertheless Fig. 2b shows that the observed Fmin variations are similar for both devices and that they are not significantly influenced by the kink effect occurring within one of the devices. We therefore believe that multiplication noise in HEMTs resulting from impact ionization is either lower than in MESFETs or more probably mainly generated in a region between gate and drain where it is not amplified by the device internal gain so that the regular noise remains predominant.

IMPACT of PARALLEL CONDUCTION on the MICROWAVE NOISE of HEMTs.

Fig.3a compares transconductance G_m variations measured at DC versus gate voltage (V_{DS}=2 V) of two different devices. The first one is the pseudomorphic HEMT referred to as HM in the previous section and the second is a standard HEMT (NE32183 featuring a 0.3x200 um gate area) referred to as HNE. Fig.3a indicates that the G_m of device HNE peaks at 0.4 Idss which denotes a severe parallel conduction within the GaAlAs layer. On the contrary the monotonic G_m increase observed for device HM rules out any significant parallel conduction. The corresponding minimum noise figure variations observed at 18 GHz are shown in Fig. 3b: the sharpest Fmin increase versus I_{DS} observed for device HNE is an indication of the detrimental influence of parallel conduction on microwave noise performance.

II.CONCLUSION

To prevent severe noise degradation in MESFETs microwave amplifiers due to impact ionization in the channel some simple precautions have to be taken: if an hybrid assembly is used, MESFETs have to be screened in terms of kink effect; otherwise (MMIC for example) they would have to be operated at low drain voltage below the kink effect voltage (typically 2 to 2.5 V). An advantage of HEMTs over MESFETs is that the noise performance is rather insensitive to the kink effect.

On the contrary the HEMT microwave noise performance is influenced by parallel conduction within the low mobility GaAlAs layer occurring at large drain current. Thus only those devices that have no parallel conduction can be operated at bias conditions providing simultaneously a low noise figure and a large power gain. Pseudomorphic HEMTs more easily fullfill these requirements since parallel conduction is more unlikely to occur due to the larger potential barrier between GaAlAs and GaInAs.

III. REFERENCES

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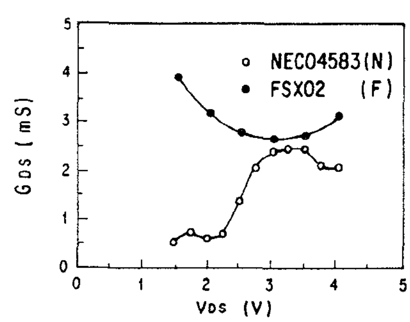

Fig. 1a
DC conductance GDS versus VDS

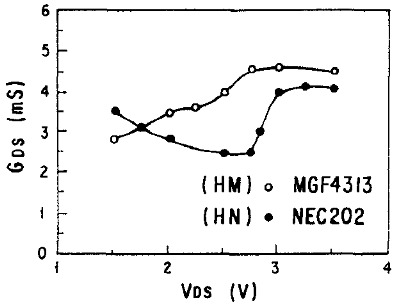

Fig. 2a
DC conductance G_{DS} versus V_{DS}

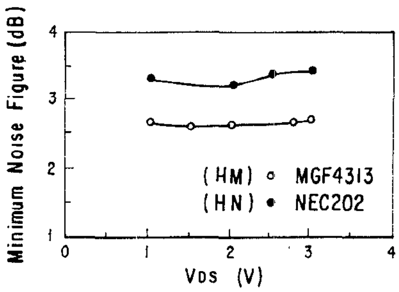

Fig. 2b
Minimum Noise Figure (dB) versus V_{DS}

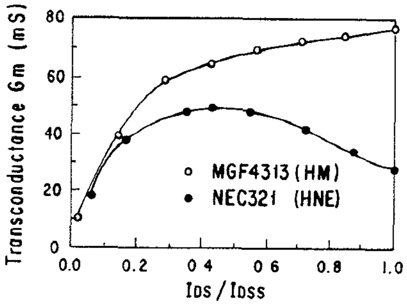

Fig. 3a
Transconductance G_M (mS) versus Drain current (I_{DS}/I_{DSS})

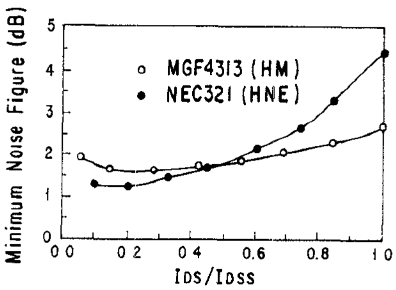

Fig. 3b
Minimum Noise Figure versus Drain Current (I_{DS}/I_{DSS})

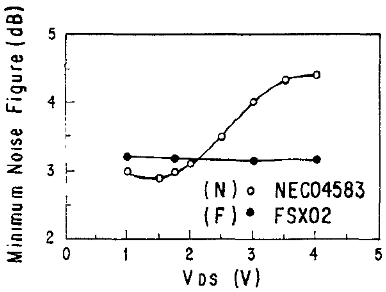

Fig. 1b
Minimum Noise Figure (dB) versus V_{DS}