A NEW METHOD FOR ON-WAFER HIGH FREQUENCY NOISE MEASUREMENT OF FET's

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ABSTRACT:

A new method for determining the equivalent noise resistance Rn and the magnitude of the optimum generator admittance |Yopt| is described.This method is based on the fact that the real part of the correlation admittance can be neglected. A new method for determining the other noise parameters Γopt and Fmin without automatic input tuner is then proposed.

INTRODUCTION

The on-wafer measurement of high frequency noise is known to be a difficult problem. To date, different systems are commercially available for noise measurement up to 26.5 GHz. Basically, these systems are based on the same approach.The noise measurements are made for several source admittance presented to the DUT and the noise figure is determined by fit of the theoritical relation between the noise parameters and the source admittances.In this paper, we present a new method for on-wafer measurement of the equivalent noise resistance and optimum generator admittance magnitude of FET'S and HEMT's: A new method for determining the noise figure is then proposed. This method has the following features.

- no need of an automatic input tuner.

- very well suited for measurement in the mm-wave range.

THEORETICAL ANALYSIS:

For any source admittance,the noise figure F of any two-ports is given by:

$$(1)\ F = Fmin + Rn/Gs.|Ys\text{-}Yopt|^2.$$

$$\text{with } Fmin = 1 + 2Rn\,[Gopt + Gcor]$$

In this expression, Rn is the equivalent noise resistance, Yopt = Gopt + j Bopt is the optimum generator admittance, Ys = Gs + j Bs is the generator admittance presented to the DUT and Ycor = Gcor+j.Bcor ,is the correlation admittance [1]. In the case of field effect devices, (MESFET's or HEMT's) all the theoretical analysis [2],[3] show the following features:

- The equivalent noise resistance Rn is frequency independent as far as the gate parasitics (inductance and capacitance) can be neglected [4].

- Gopt and Bopt are proportional to ω [1].

- Gcor is very small as compared with Gopt and it increases as ω^2. As a consequence, the noise figure can be approximated by (1 + 2 Rn Gopt) and, in fact, THREE noise parameters are sufficient to described the device noise properties.

These properties are quite general as far as the operating frequency is lower than the intrinsic cutoff frequency Gm/2πCgs. In the case of a 50 Ω source impedance ($Ys = G_0 = 20$ mS) the expression (1) becomes:

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$(2)\ F_{50} = 1 + RnG_0 + 2RnGcor + Rn/G_0|Yopt|^2$

This expression is very important for two main reasons:

(i) Since Gcor and $|Yopt|^2$ vary as ω^2, the frequency variation of F_{50} versus ω^2 is linear and the F_{50} value at $\omega = 0$ is $(1 + Rn\ G_0)$. So, Rn can be easily deduced from the F_{50} value at low frequency with a very good accuracy.

(ii) Since Gcor is very small as compared to $|Yopt|$, the slope of F_{50} versus ω^2 provides $|Yopt|$.

So, the measurement of the noise figure with 50 ohms input impedance, F_{50}, as a function of frequency provides two important noise parameters Rn and $|Yopt|$ with a good accuracy because this measurement is very simple.

Figure (1) shows the evolution of F_{50} versus ω^2. This figure shows that F_{50} increases linearly versus ω^2 what is in good agreement with the theory.

At this step two strategies are possible:

- if the conventional method with an automatic input tuner is used,the preceding measurement can be used to reduce the number of unknowns and therefore to reduce the number of input admittances needed for the whole noise characterization.As a matter of fact, only Bopt (or Gopt) has to be measured because $|Yopt|$ is known.

- if no automatic tuner is available,a device with a long gate access can be used as described now.

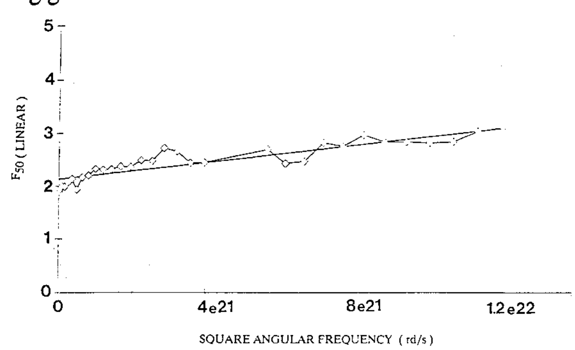

FIGURE 1: Experimental evolutions of F_{50} versus (from 0.5 GHz to 17.0 GHz)

THE NEW METHOD FOR DETERMINING THE NOISE FIGURE

A device with long gate acces has been realized in our laboratory and is shown in figure (2). Using this kind of device the noise measurement method is the following:

- F_{50} is measured by contacting the probe at the end of the line (position a).

- Another measurement is made by contacting the probe just near the device (position b).In that case,the ideal admittance presented to the DUT is $Y = G_0\,(1 + j\,tg(\beta l))$ and the noise figure is given by :

$$(3)\ F = F_{50} + Rn\,.\,tg(\beta l)\,.\,(G_0.tg(\beta l) - 2Bopt)$$

- Bopt can be deduced from equation (3).

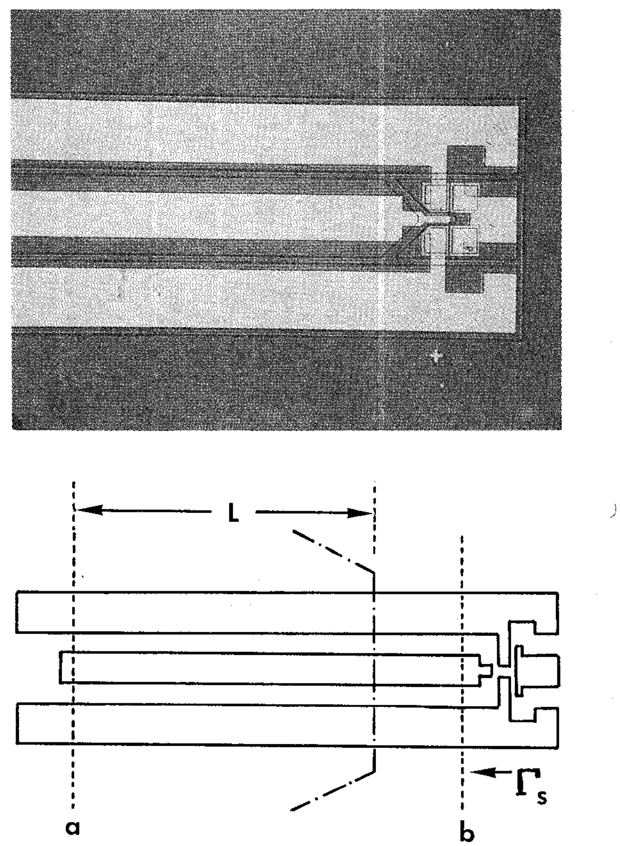

FIGURE 2: Long gate access FET's for direct noise characterization.

In addition, other probe positions between positions (a) and (b) can be used as redundand measurement because for any probe position,the admittance presented to the DUT is very well known.This admittance is shown between 2 and 26.5 GHz for various probe positions on figure (3). In practice, the line length has to be chosen according to the measurement frequency and this line has to be shorter with increasing measurement frequency.

Obviously the imperfections of the measurement set up have to be introduced:

- the probe impedance is not exactly 50 ohms.

- the gate line characteristic impedance is not exactly 50 ohms and this line has some losses.

These imperfections can be measured and introduced in the method.Obviously equations (1) and (3) becomes more complicated but the method presented remains valid.

In taking in account these imperfections, the two other noise parameters, Bopt (then Γopt) and Fmin are directly obtained.

Figures (4) and (5) show the experimental variations of Γopt and Fmin versus frequency , using the device shown in figure (2) and the analytical approach developped in this work.

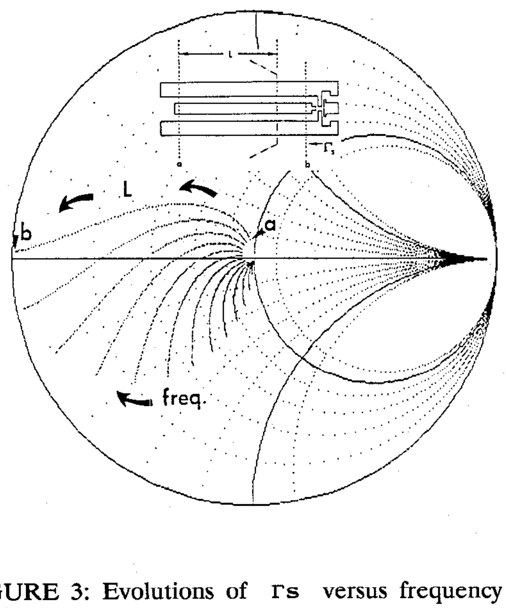

FIGURE 3: Evolutions of Γs versus frequency of 50 ohms open line for different probe positions.

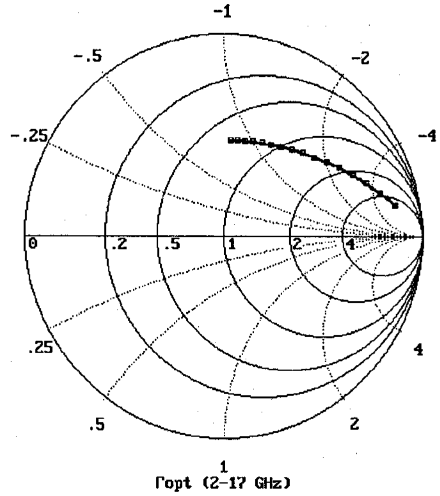

FIGURE 4: Experimental variations of Γopt versus frequency
(from 2 to 17 GHz).

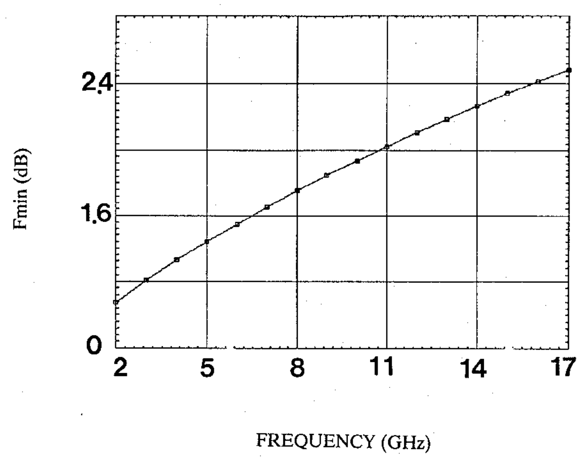

FIGURE 5: Experimental Variations of minimum noise figure (Fmin) versus frequency (from 2 to 17 GHz).

CONCLUSION:

A new method for the noise parameters measurement has been presented.This method is based on the concept that the four noise parameters in the case of MESFET and HEMT are not independant.In practice only Rn,Gopt and Bopt have to be determine because Gcor is very small.We have shown that Rn and |Yopt| can be deduced from the measurement of F_{50} versus frequency.For the determination of Gopt and Bopt,the use of device with a long gate access is well suited.

This new technique has several advantages:

- no automatic tuner is necessary.
- the modification of the input admittance is performed near the device.
- the method can be used at any frequency and is more suited in the mm wave range because the input line has to be shorter.
- easy to develop on conventional microwave wafer probe system.

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