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# SIGNAL AND NOISE PROPERTIES OF TWFETS (MODEL, CONCEPT, AND POTENTIAL)

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## Abstract

We report mm-wave signal and noise performance of a TWFET (Traveling-Wave FET). For the first time a CAD model (with possibility of including temperature dependence) for simultaneous signal and noise performance determination, based on coupled modes theory and full semidistributed modeling [4], is here proposed.

## 1- Introduction

Recent researchs in the field of traveling-wave FETs (Fig. 1) show the important role of this device for future millimetre-wave applications. Although some work has been done on signal properties [1], [5], the noise performance study and the CAD-oriented modeling of this amplifier has not been accomplished so far.

Historically, the idea of the traveling-wave FET (TWFET) has been given by Mciver [7] for a MOSFET. By considering only the active coupling he has shown that gain can be increased by increasing device's gate width. In the following directions, different solutions have been suggested, reported in [2], in order to improve signal performance of the device. The first realized TWFET was presented by Holden *et al* [6] from Plessey showing a 3 dB gain over 5-10 GHz frequency range. Recently Anand *et al.* [1] by applying distributed theory to two coupled lines, have proposed a TWHEMT for millimeter-wave applications.

In this paper, we will present a complete approach of simultaneous signal and noise modeling, based on the three coupled transmission line theory and full semidistributed FET's model [2], of TWFETs. We believe that these devices can provide a high gain and low noise performances over an ultra large band frequency.

## 2- Design procedure of a TWHEMT

The four important considerations and the recipes for designing an ultra large band, high gain and low noise TWFET are the followings :

1- Synchronisation of wave velocity at gate and drain electrodes. (to increased frequency band width and possibility to have a high gain).

2- Suitable load at the ends of electrodes (to have a matched condition for the progressive wave).

3- A high transconductance per unit length $g_m$ (to improve device's signal and noise performances).

4- Choosing an appropriate gate width (keeping in view gain, stability, and gain flatness problems).

Using FETs full semidistributed modeling and distributed theory [4], a distributed drain capacitance ($C_{synch.}$) is used in order to synchronise the wave velocity at drain and gate lines (Fig. 2). This capacitance has an important influence on the eigenmodes of the structure of transistor and gives the condition of existance of the progressive mode (wave). Then a suitable load termination is placed at the end of drain and gate electrodes $Z_d$ and $Z_g$ (generally the characteristic impedance of each line). In our study the parallel resitances and inductuances were choosen for $Z_d$ and $Z_g$. Concerning the $Z_s$, the value of a classical FETs was adopted for this element. For high gain and low noise purposes a device with a high transconductance per unit length $g_m$ (pseudomorphic or lattice-matched HEMTs) was choosen. Then a suitable gate width value (W) was used in order to control device response (gain, stability, gain flatness, low input/output VSWR).

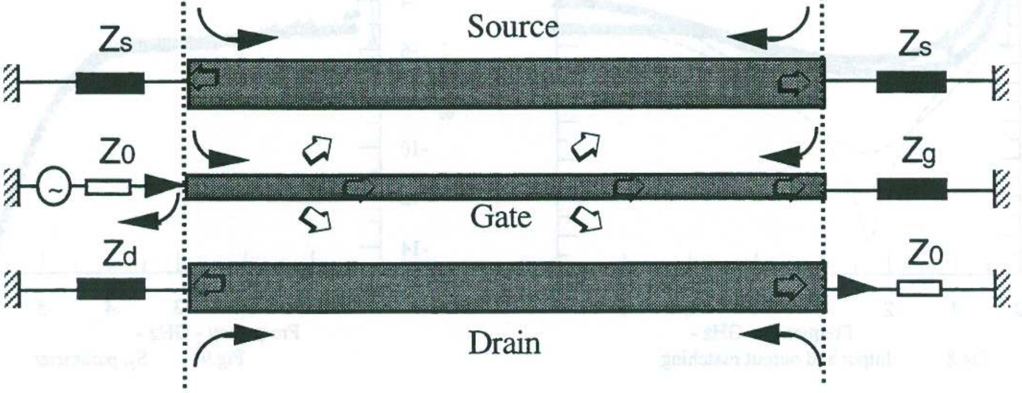

Fig. 1- Representation of a traveling-wave FET (TWFET)

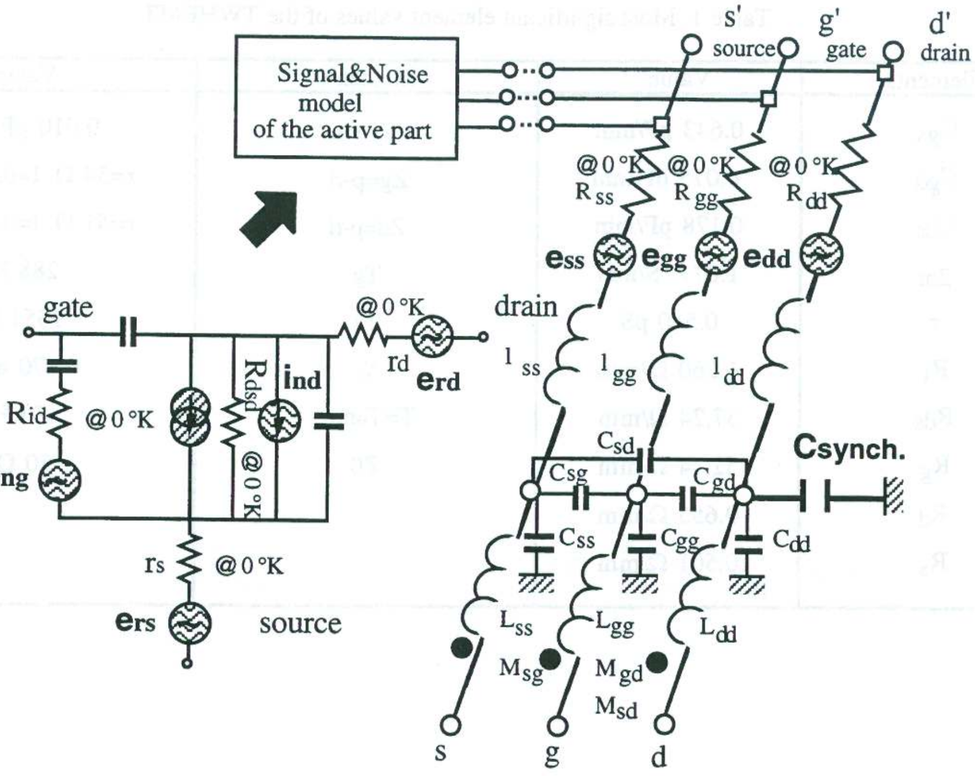

Fig. 2- Full semidistributed signal and noise modeling of TWFET (elementary cell).

One can study the signal and noise performances by applying the simultaneous determination of signal and noise algorithm [2] (including temperature dependence) as follows :

$$C^Y(V_{gs}, V_{ds}, f, T) = H_N.C_P{}^Y.H_N{}^\dagger + H_J.C_J{}^Y.H_J{}^\dagger$$

$$Y(V_{gs}, V_{ds}, f, T) = Y_{ee} + H_J.Y_{ie}$$

(1)

where

$C^Y(V_{gs}, V_{ds}, f, T)$ and $Y(V_{gs}, V_{ds}, f, T)$: are the admittance noise correlation matrix and admittance matrix of the device respectively at bias points ($V_{gs}$, $V_{ds}$), frequency $f$ and temperature $T$.

$C_P{}^Y$ : is the admittance noise correlation of the passive part (determined from signal matrix).

$C_J{}^Y$ : is the admittance noise correlation of active slices

$H_N$ and $H_J$ : are the matrices that are computed from passive and active signal matrices.

$Y_{ee}$ and $Y_{ie}$ : can be determined from signal matrix.

Temperature noise constants extraction of such devices can be done using the algorithm given in [8].

## 3- Results

The procedure was used to study of the TWHEMT performance where the most relevant element values are reported in Table 1. These values correspond to signal, noise and stability considerations of the device. In this study, the goal was to design a TWFET amplifier with a 8 dB stable gain in the 10-100 GHz band. The value of $g_m$ in table 1. corresponds well with pseudomorphic or lattice-matched HEMTs [3]. In order to study the variation of the minimum noise figure Fmin as a function of the drain temperature noise constant $T_d$ (Pospiezalski's noise model), $T_d$ was varied between 1000 - 10000 K and the maximum deviation of Fmin from the value shown in Fig. 3 was 2 dB. The values of temperature noise constants in table 1 correspond to the typical values of these constants for pseudomorphic or lattice-matched HEMTs [9].

Fig. 3 shows the signal and noise performances and potentials of the studied TWHEMT. One remarks the excellent performance (signal and noise) of this device for mm-wave applications.

## 4- Conclusion

Signal and noise properties of an ultra large band and low noise TWPHEMT suggest the interest of such devices for MMIC and MWMMIC technology. Low gate width dimension, simple design procedure and signal and noise performances distinguish TWHEMT from classical distributed amplifiers and our results demonstrate the superiority of TWHEMT in high frequency applications. One can reamark also the facility for matching the device for minimum noise figure (small deviation between Fmin and device noise figure corresponding to 50 Ω source impedance F(50 Ω)).

Table 1. Most significant element values of the TWHEMT

| Elements | Value | Elements | Value |
|---|---|---|---|
| $C_{gs}$ | 0.643 pF/mm | Csynch. | 0.010 pF/mm |
| $C_{gd}$ | 0.075 pF/mm | Zg=p-rl | r=54 Ω, l=0.020 nH |
| $C_{ds}$ | 0.178 pF/mm | Zd=p-rl | r=51 Ω, l=0.096 nH |
| $g_m$ | 1.071 S/mm | Tg | 288 K |
| $\tau$ | 0.540 pS | Td | 1551 K |
| $R_i$ | 1.260 Ω/mm | W | 0.670 mm |
| $R_{ds}$ | 37.24 Ω/mm | T=Tamb. | 293 K |
| $R_g$ | 52.14 Ω/mm | Z0 | 50 Ω |
| $R_d$ | 0.655 Ω/mm | | |
| $R_s$ | 0.501 Ω/mm | | |

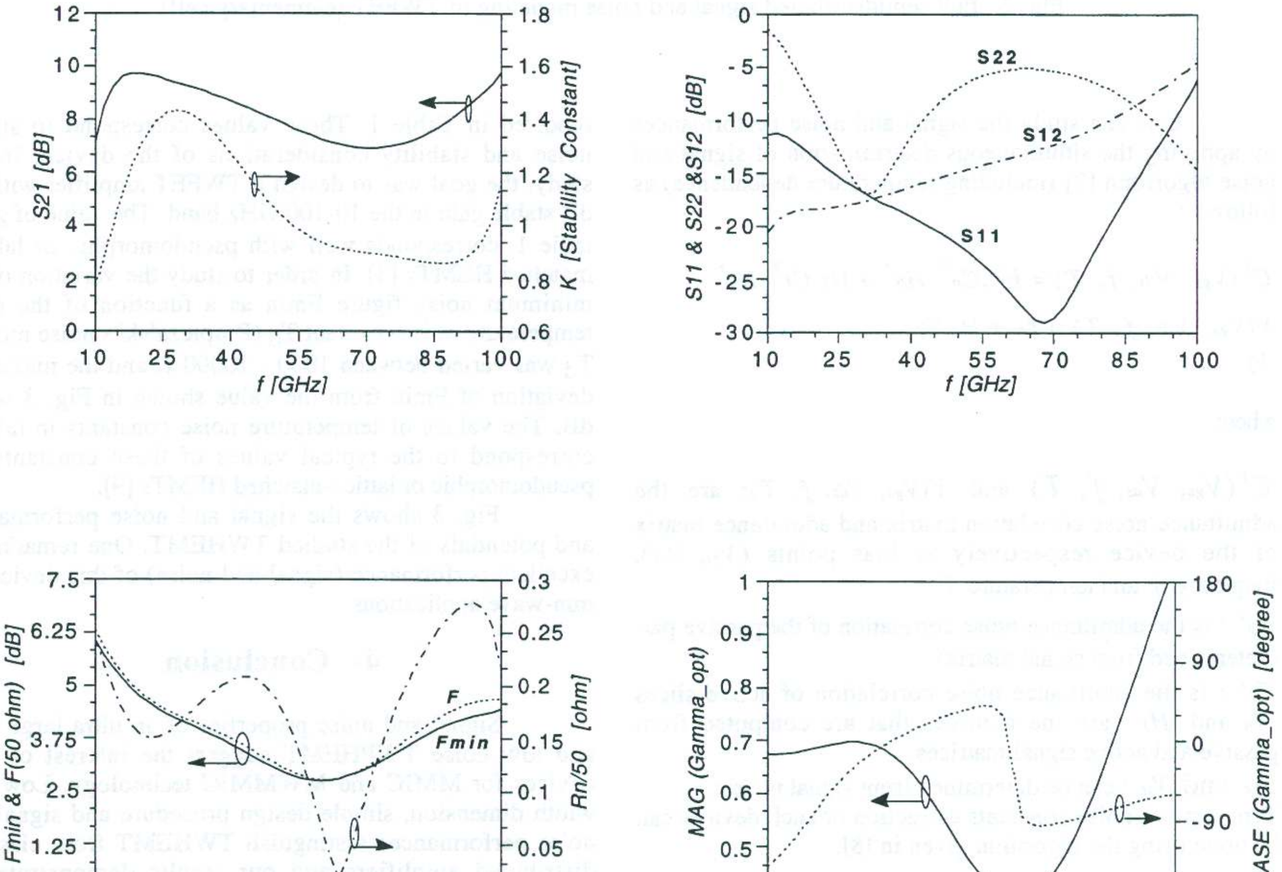

Fig. 3- Signal and noise performances of TWHEMT

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