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Helena: A Physical Modeling for the DC, AC, Noise and Non Linear HEMT Performance

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Abstract

A friendly software for the modeling of HEMTs called HELENA for **H**emt **ELE**ctrical properties and **N**oise **A**nalysis is presented. Using this software, the DC, AC, noise and non linear performance of any kind of HEMT realized on either GaAs or InP substrates can be obtained. HELENA is very fast and gives results in a good agreement with experiments.

1. Physical model used in HELENA

The physical HEMT modeling used in HELENA is based on the quasi-two dimensional (Q2D) approach [1, 2, 3, 4]. However, significant improvements have been introduced as compared with the previously published works.

- Concerning the charge control law determination, a new model including quantum effects has been developed for HEMT layers [5]. This new model is faster than the self-consistent resolution of Schrödinger and Poisson's equation although it gives results in good agreement with the more rigorous model and with experiments. As a consequence, it is well suited for the Q2D modeling of HEMTs.

- For the AC and noise performance, the device is considered as a non uniform active line, and the electrical properties are calculated using the method described in [6]. A key feature of this approach is to provide all the small signal parameters (Gm, Gd, Cgs, Cgd, Ri, τ, Rgd, Cds), the S-parameters as well as any small signal performance at any frequency of operation. The noise performance is calculated using the impedance field method [7] associated together with the correlation matrix approach [8]. The main advantage of this method is its validity in the millimeter wave range, contrary to the modelings based on the quasi-static approach. The details of the method used are well described in [9].

The latest improvements included in the physical modeling concern the reverse gate leakage current (GLC) of the schottky barrier, and the calculation of the non linear device parameters. The gate leakage current effect is important because it introduces a parasitic conductance at the device input and also adds shot noise sources that influence the noise performance [10].

As an example, figure (1) shows the minimum noise figure Fmin versus frequency, for differents values of the GLC in the case of a 0.4 x 100 μm² PM HEMT. As expected, the GLC strongly degrades the minimum noise figure, especially at low frequencies.

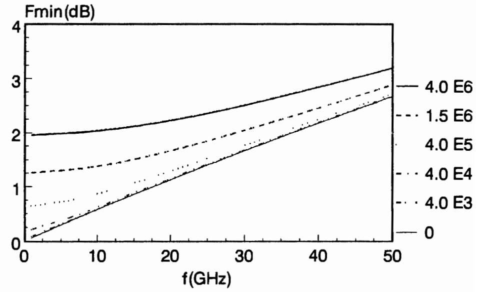


Figure 1. Influence of gate current on Fmin

When the DC and AC performance is calculated, the non linear device behaviour is deduced. The Ids(Vds, Vgs) and Q(Vds, Vgs) relationships are fitted using usual modeling (Curtice, Tajima, Materka ...). The non linear modeling based on the active line method is also available. These non linear parameters can be directly used in the circuit simulators.

2. Software description

The physical model previously described is included in the friendly software called HELENA. All the physical and technological parameters are easily introduced and file-managed thanks to pull-down menus and data illustrations. The results are displayed in a convenient form using linear or logarithmic scales as well as polar or Smith chart when it is necessary. The flow chart of the software is shown in figure (2).

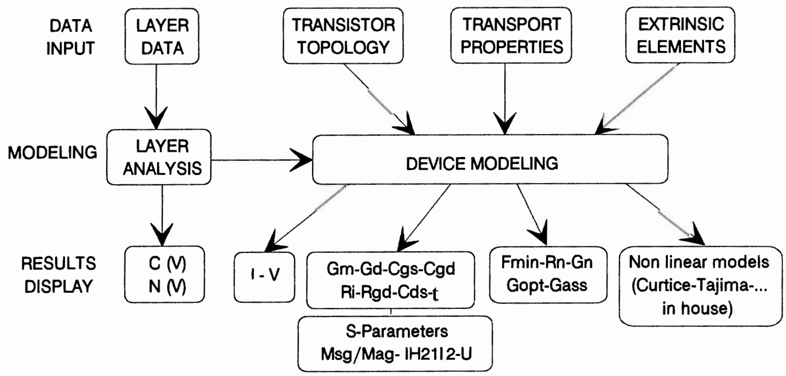


Figure 2. HELENA flow chart

It is divided in three different blocks: data input, modeling of HEMT performance and results display.

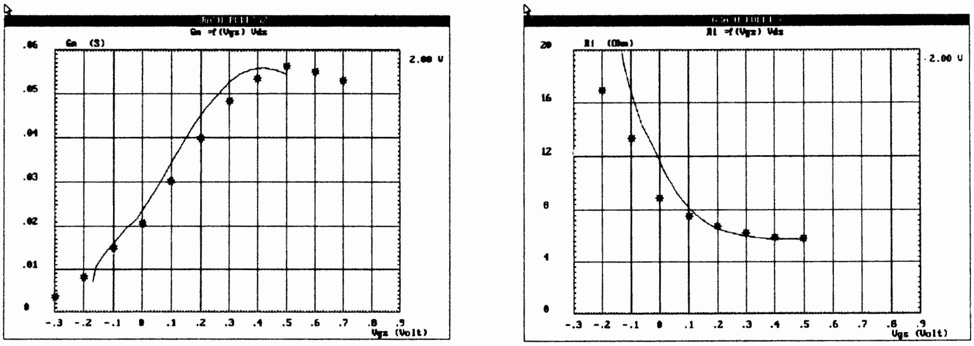
Two main routines are used for the device performance calculation: in the first step the layer analysis is made, and in the second step, DC, AC, noise and non linear performance of the device are calculated.
The device library contains the following structures:

- GaAlAs/GaInAs/GaAlAs system on GaAs.
  Pseudomorphic - Conventional HEMT - Epitaxial or implanted MESFET.
- AlInAs/GaInAs/AlInAs system on InP: Lattice-matched - Pseudomorphic.

HELENA is now running on PC with MSDOS operating system. HELENA is very fast (about 3 mn are necessary to make a DC, AC and Noise analysis of a device with a 486/33MHz personnal computer). HELENA is then an interesting tool for the device optimization as well as for the C.A.D. of microwave and millimeter wave circuits.

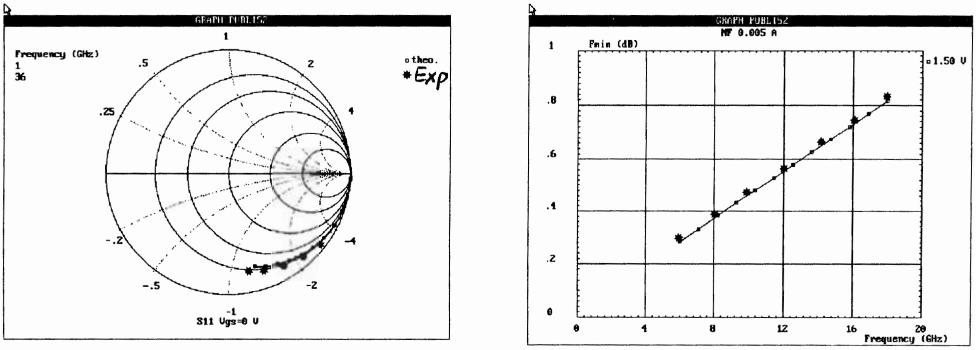
3. Comparison with measurements

The validity of HELENA is obviously an important problem and a number of comparisons between theoretical results and experimental measurements have been carried out. The structure used for this comparison is a 0.20 x 48 μm^2 gate device realized by THOMSON-LCR on a PICOGIGA delta-doped pseudomorphic layer. To make a comparison, it should be noted that no fitting parameters have been introduced for the intrinsic device simulation while the value of the parasitic elements, needed for the extrinsic performance calculation, have been deduced from measurements. Figures (3:a-d) shows the comparison between theoretical and experimental results for the intrinsic transconductance Gm, the intrinsic resistance Ri, the S_{11} parameters in the frequency band 1-36 GHz, and the minimum noise figure F_{min}. The experimental noise results have been obtained using a new on-wafer measurements [11]. As is shown, HELENA gives results in a good agreement with measurements.



(a) (b)

Figure 3-a-b. Comparison between the theoretical (solid line) and experimental (points) intrinsic elements: (a) Transconductance versus Vgs; *Vds* = 2V. (b) Intrinsic resistance versus Vgs; *Vds* = 2V.



(c) (d)

Figure 3-c-d. Comparison between the theoretical (solid line) and experimental (points): (c) S11 parameters: *Vgs* = 0; *Vds* = 2V. (d) Minimum noise figure *Ids* = 5mA; *Vds* = 1.5V.

4. Conclusion

A friendly software called HELENA has been presented. Based on a quasi-2D model, HELENA provides all the electrical performances of many kind of HEMT with a short computing time and a good accuracy. It is then well suited for the study of systematic influence of device parameters. In order to easily integrated HELENA in the microwave circuits environnement, the work station version of the software will be available in the future.

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