Microwave Active Devices modeling using Verilog-A description language

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Abstract - The long term impact of microwave communication technologies will be functionality simulated and design on traditional computing and usual RF and microwave communication simulators such us: PSPICE, Agilent ADS, Agilent GENESYS, AWR Microwave Office, etc. This ability, allows making possible the enabling of the digital computer interaction and simulation with the designer and the world around it. This paper shows the simplicity and friendly-to-use technique of modeling active microwave devices using Verilog-A language, several examples has been studied under different commercial simulators: Agilent ADS and Genesys.

Key Words - Microwave, FET, MESFET, P-HEMT, HBT, microwave transistor, modeling.

1. Introduction

Verilog-A language was recently enhanced to provide greater support for microwave devices compact modeling thru the European TARGET network [1]. In this paper, to become the standard language for microwave devices, two different aspects of compact microwave model development and implementation, are necessary: compact model developers must be come familiar with the language, and designers must run microwave compact models written in Verilog-A language almost as quickly and reliably as those hand coded in C language.

Modern high frequency, high performance system-on-chip design is heading to include more and more analog or mixed signal circuits as well as digital blocks. As the complexity of a system grows, it becomes more and more important reason to implement the system simulation and microwave top-down design methodology as well. Verilog-A [2-3], which is studied in this paper, is one of the most excellent top-down hardware description languages specifically for microwave analog and mixed signal designs. Its compatibility with pure digital hardware description languages (HDLs), such as Verilog and VHDL, is one of the most important advantages. In addition, the top-down characteristics make Verilog-A able to achieve microwave system-level simulation that MATLAB™ [4] usually does.

The standard language of compact modeling in the last decade has been C programming language since about 1985, when SPICE 2 was re-written from original FORTRAN (Formula translator) into C language (SPICE 3). Most recent compact models have been written in C

code (like AWR Microwave Office), although some still use FORTRAN language.
The Compact Model Council [5] has preferred C code in the past, but it encourages the release of Verilog-A source code for its next-generation of MOSFET model standardization effort. The Verilog-A hardware description language [5], was recently enhanced to provide greater support for compact modeling by the release of the Verilog-AMS Language Reference Manual (LRM) version 2.2.
Even yet well developed nowadays, the potential capability for synthesis with digital HDLs within a microwave simulator is another unbeatable attraction.
In this paper, several different examples of microwave devices like: microwave diodes, MESFET transistors, and P-HEMT devices, have been studied and simulated by Verilog-A to experience its advantages.
This paper addresses both of these steps: it provides a quick introduction to writing microwave device compact models in Verilog-A and, by indicating the techniques that compact model writers may use, helps simulator vendors and microwave devices manufactures understand the importance of accurate optimizations that are expected from their Verilog-A interfaces. Application-driven circuit-level design methodologies that ease the integration of the simulation domain to the real world using different technologies are therefore needed.

2. Advantages of VERILOG-A code

One important reason for preferring Verilog-A language for compact microwave modeling over general purpose programming languages, is that it frees the model developer from the handling of the modeling simulator interface [6]. Usually, the modeling user interface of simulator brand “A” is quite different in use and definition of variables of the modeling user interface of simulator brand “B”. And as a consequence of this, is very difficult to implement the same model in different simulators without additional programming and compiling errors, at the fist trial.
The main advantage of Verilog-A language is that it is a “universal” language, so if the microwave developed model works properly in one simulator, the same source code will work properly in other simulator capable to manage Verilog-A files, and this managing is transparent for the model developer and microwave designer. Furthermore, Verilog-A simulators automatically compute symbolic partial derivatives of the currents and charges in a compact model and determine the proper insertion of these values into the Jacobian matrix for Newton’s method. This feature is very interesting in the study and description of the intermodulation distortion phenomena.
The computation of these derivatives must be done by hand in C language based simulators. Thus, even if one is modifying an existing compact model in C code, in which most of the interface work has already been done, one still has to compute new derivatives, and possibly get new matrix pointers, when introducing a new dependence.
The microwave model developer is focused on getting correct equations for currents, which are compared against measurements, and usually, the derivatives are harder to verify. As a direct result, almost every hand-coded or behavioral compact model has had some derivative errors in its first release.
Most microwave foundries, have switched to commercial simulators, but they do not have the leverage to insist that proprietary models be implemented in these microwave high level simulators. With Verilog-A, new models can be added almost as quickly as the equations can be defined. The semiconductor company has control over the implementation schedule, and it can maintain control of the intellectual property of the model within different simulators.

3. Simulations

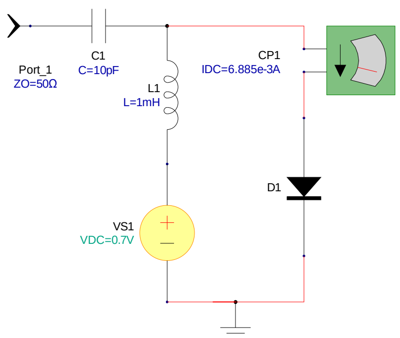
In this work, the same Verilog-A file has been created, compiled and simulated using two different commercial simulators: Agilent Genesys and Advanced Desing System (ADS). The source code for a generic microwave diode file is shown in Table 1.

```
***   Verilog-A FILE;
`include "disciplines.vams" `include "constants.vams"
`include "compact.vams"  module diodo_va(anodo,catodo);
inout anodo, catodo; electrical anodo, catodo, interno;
parameter real Is  = 2e-12 from (0:inf];
parameter real alpha  = 32 from (0:inf];
parameter real beta  = 0.2 from (0:inf];
parameter real Rs  = 2 from (0:inf];
parameter real Cjo  = 2e-12 from (0:inf];
parameter real Vj  = 0.9 exclude 0;
real Vd, Id, Qd, Qf, Qr;
analog
        begin
                Vd = V(interno, catodo);
                //Diodo intrínseco
                Id = Is * (limexp(Vd * alpha) -1);
                //Capacidades (de unión y difusión)
                Qf = Cjo*(Vd-beta*Vj+pow((Vd-beta*Vj),2)/(4*Vj*(1-
                    beta)))/sqrt(1-beta)-2*Cjo*sqrt(Vj*(Vj-beta*Vj));
                Qr = -2*Cjo*sqrt(Vj*(Vj-Vd));
                if (Vd < beta*Vj)
                Qd = Qr;
                else
                Qd = Qf;
                I(interno, catodo) <+ Id+ddt(Qd);
                V(anodo, interno) <+ I(anodo, interno) * Rs;
        end
endmodule
```

Table.1. Source Verilog_A code file to be compiled within two different microwave simulators

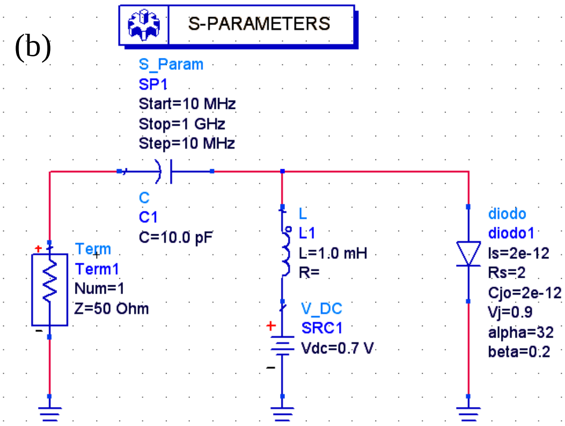
4. Results

As an example of portability and accuracy of results of the Verilog-A language modeling microwave circuitry, the result of simulation on a microwave diode is shown in Fig.1. The source file shown in Table 1 has been simulated under Agilent ADS and Genesys microwave simulators, for DC and scattering.

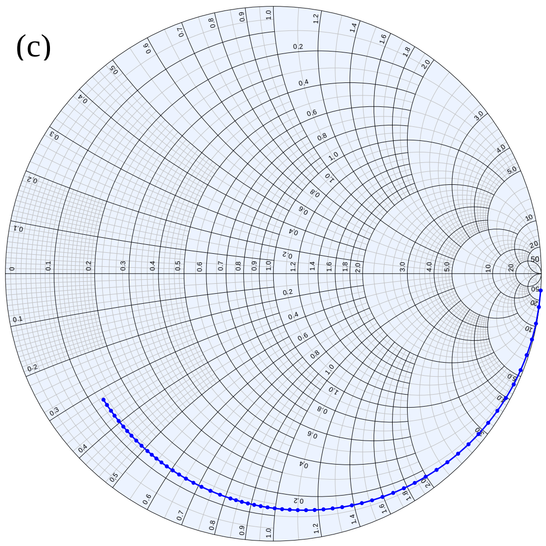


(a)

(b)



(c)



(d)

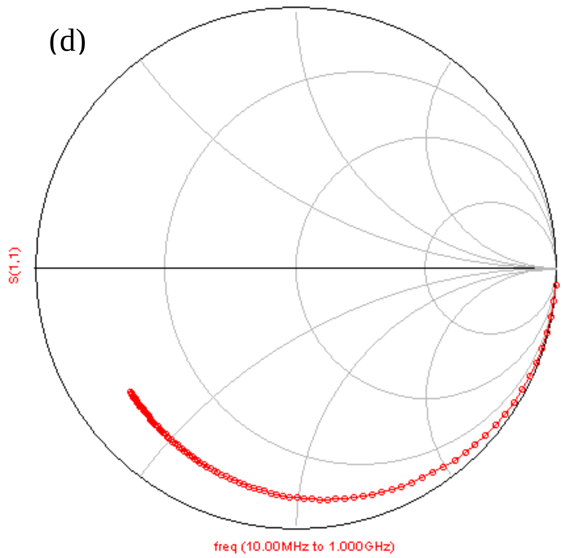


Fig.1. Schematic used to simulate the microwave diode in GENESYS simulator (a) and ADS (b) using the same Verilog-A source code file.
(c) S11 parameter computed using GENESYS simulator and Verilog-A modeling.
(d) S11 parameter computed using ADS simulator and Verilog-A modeling.

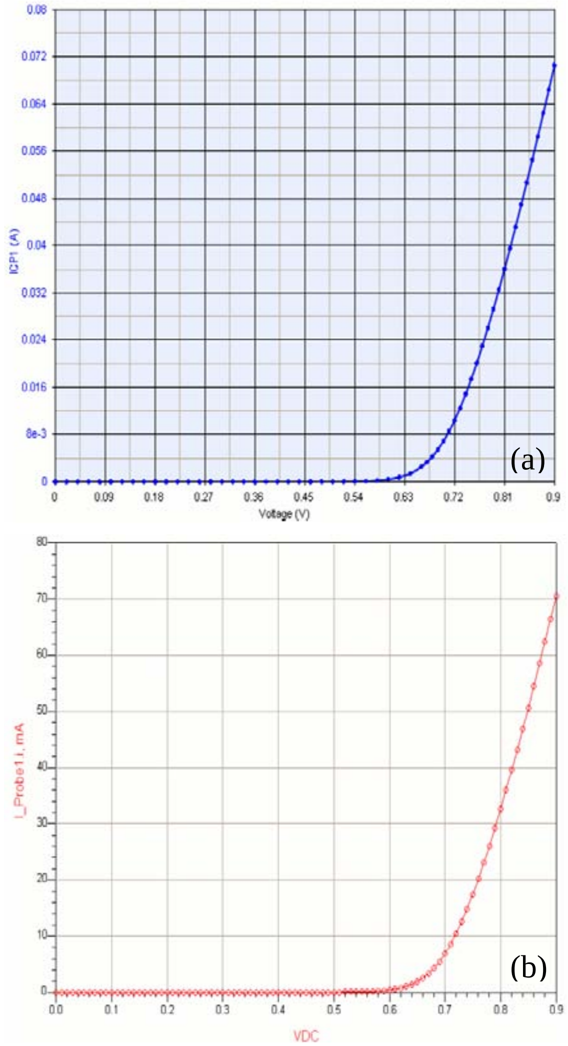


Fig.2. (a) Microwave diode I-V curves computed using GENESYS™ simulator and Verilog-A modeling.
(b) Microwave diode I-V curves computed using ADS™ simulator and Verilog-A modeling.

Figs 1 (a) and (b) show the schematic circuits used in the simulation, to compute the I-V DC curves and the Scattering parameter S11 of the microwave diode using both simulators.
Fig 1 (c), and Fig 1 (d) show the small-signal scattering simulation of S11 made with GENESYS and ADS, respectively for the mentioned diode.
Finally, Fig 2 (a) and (b) show the comparison between computed I-V curves using ADS and Genesys.
As it can be inferred of these figures, results are identical for both simulations: DC and scattering, the unique difference is the aspect of the graphical interface of the microwave simulator.
A direct consequence of this is the ability of use the same source code within different commercial microwave simulators.

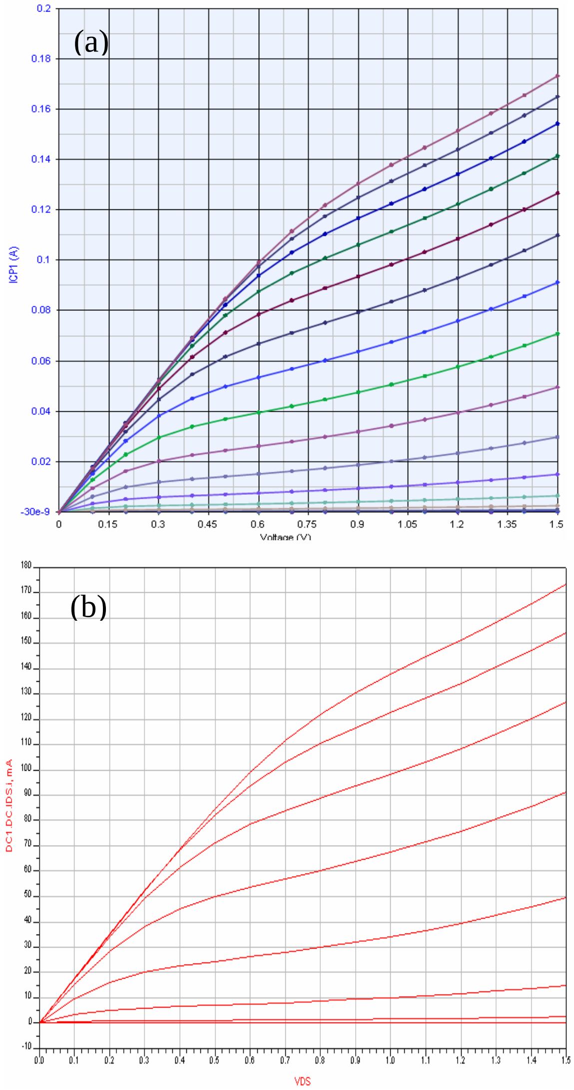


Fig.3. (a) Microwave diode I-V curves for a HEMT transistor computed using GENESYS™ simulator and Verilog-A modeling.
(b) Microwave diode I-V curves for a HEMT transistor computed using ADS™ simulator and Verilog-A modeling.

Finally, in order to generalize the use of Verilog-A to more complex microwave active devices, a microwave P-HEMT transistor including the thermal effects has been simulated using the Verilog-A language, using ADS and Genesys simulators.

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The transistor model used in the present work is based in our previously reported microwave active FET model [7].
Fig. 3 (a) and Fig 3 (b) show the simulated I-V curves in Genesys and ADS for the same device, As a consequence, of these figures, the result I-V curves are identical for both microwave simulators. A more illustrative explanation (including the source code in Verilog-A language) of the procedure of the implementation of the model within the simulators and small-signal simulations have been reported in [8]. Taking into account these results, Verilog-A is an interesting and easy to use tool to develop and simulate microwave models of active devices

5. Conclusion

It has been demonstrated that Verilog-A language is suitable to properly model and simulate microwave active devices. The ability of re-use the same source code within different commercial simulators is very important for modelers and designers, in order to exchange the same model between different simulators, and it is no necessary to modify the model in order to change of simulation platform.

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