COMPARISON OF SOFTWARE TOOLS FOR THE DESIGN OF MICROWAVE COMPONENTS

Dr Richard Jenkins, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK
email: *r.jenkins@cranfield.ac.uk*

Dr Y. Xu and Prof. R. Roy, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

Dr C. Alabaster, Department of Information & Systems Engineering, Cranfield University, Shrivenham, OXON SN6 8LA

K. Harris, S. Jenkins and N. Mead, Specialist Microwave Solutions SMS Ltd., 3 Medway Court, University Way, Cranfield Technology Park, Cranfield, Beds MK43 0FQ

Abstract

Software packages are an essential requirement for the design of microwave components. Their use prevents the costly process of redesigning and rebuilding prototypes and often ensures a final design that gives a close-to-optimal performance. This paper will analyse the capabilities of the available design software packages, including those purchasable from the well-known companies, such as AWR, Agilent and Ansoft. Important features of each software package will be listed against the requirements for accurate modelling. Other important considerations for the use of design software will also be included in this comparison, such as user-friendliness, approximate cost and range of vendor libraries.

1   Introduction

Software tools for computational design are generally used in the microwave industry to reduce the cost of production and to achieve an optimal performance. The production of a component involves the design, fabrication, test and tuning. Use of design software replaces the design and tuning stages of the production by computational design and optimisation thus drastically reducing the labour time and cost of design and re-tuning in the production stage. The traditional non-computational methods of design build, test and tuning does not enable the optimisation process to be thorough and complete [1]. Computational optimisation allows a complete sensitivity analysis to be carried out and leads to more accurate designs and a final tuned design in the first build; known as 'first pass design success'. As it takes far less time to complete a final design, it is more cost effective than the traditional methods [2].

The mainstream 'professional' design packages integrate linear and nonlinear models, EM (electromagnetic) simulation and can also include time domain modelling. The capabilities of these 'professional' microwave design packages will be the first topic of discussion in the next section.

This paper will also discuss software tools for microwave circuit design that do not have the integrated capability. These programs exclusively adopt a particular type of routine, e.g. a time domain solver or an electromagnetic analysis. Time domain models generally use a SPICE routine [3]; a popular choice for microwave design is HSPICE [4]. Electromagnetic

analysis software for the use of microwave circuit design either simulates a 3D planar model, where a method of moments applied to Maxwell's Equations is used, or a fully 3D EM model is simulated, which can handle more complex 3D structures. There is a whole range of EM simulators, such as MAFIA and HFSS, for modelling complex structures, however this paper will compare only those that are most suitable for microwave circuit design.

The next section will, firstly, discuss the essential features of the mainstream fully integrated design software tools for microwave circuit design: by AWR, Agilent and Ansoft. The subsequent section will discuss the software with partial features. Section 4 will then summarise the main features of these different software tools against the important requirements of modelling capability, support, user friendliness and cost.

2   Microwave Design Software Packages

These are the well-known professional design packages with the complete range of solvers i.e. linear, non-linear, time domain and electromagnetic solvers. H-SPICE, the latest and favoured time-domain routine is incorporated into both the AWR and Ansoft design packages. In order to simulate the nonlinear behaviour of microwave components a harmonic balance routine is used.

AWR Microwave Office: This is a user-friendly software with all of the capabilities necessary for the accurate modelling and design of microwave components. MW Office contains a linear, harmonic-balance, time domain, EM simulation and physical layout. It includes linear and nonlinear noise analysis and can model nonlinear behaviour existing in microwave devices e.g. amplifiers in compression, mixers and oscillators. The layout that is generated can be used to represent the structure analysed by the software's 2.5D EM solver. MW Office cannot model fully 3D physical structures but is a powerful tool for MW circuits. An efficient layout design capability, known as iNet (intelligent Net) enables the design of, say, multi-layer PCBs to be drawn quickly and accurately. System-on-chip designs are also possible as well as a time delay neural network in order to capture memory effects. An accurate and extensive list (library) of circuit elements are also provided, which is an important requirement of accurate modelling. [5]

An additional option, known as ACE (Automatic Circuit Extraction) produces a netlist from the layout providing the most advanced elements to simulate the most accurate model (accounting for coupled line models, capacitive strays and other effects) often missed from standard designs.

AWR's sister program: Analogue Office uses HSPICE for its time domain modelling but does not feature as extensive linear and nonlinear modelling capability required for microwave component design.

Summary of Capabilities of MW Office: Linear and non-linear circuit simulator, harmonic balance engine (e.g. APLAC), X-parameters. Layout view: 2D and 3D (rotational, colour coded), transfers layout to DXF, GDSii or Gerber, a 3D planar EM simulator (EM-Sight) and a proprietary full-wave planar EM solver with advanced hybrid meshing (AXIEM).

Agilent Genesys: This is a good Windows based, user friendly design software interface and has reasonable capabilities for the design of microwave devices, but it may not be to the fullest extent of the other mainstream integrated design packages. Genesys does contain fully linear and nonlinear capabilities, a harmonic optimisation tool using harmonic balance

(Harbec), a time domain simulation SPICE routine (Ceyenne) and momentum GX/GXF (a 3D planar EM simulation). The capabilities of Genesys do include those listed in "the summary of capabilities for MW Office" with the exception of the full-wave planar EM solver. Instead, Genesys has an integrated 3D planar EM simulator with efficient meshing (Momentum GXF), which is the same as that used in Agilent ADS. Genesys also has an advanced optimisation routine with multi-dimensional parameter sweep and a Monte Carlo yield. Overall, this software does provide reasonable accuracy for the modelling of microwave elements. [6]

Ansoft DesignerRF: has all of the capabilities for the design of microwave devices. Simulation results of an example filter using Ansoft DesignerRF have been compared with those from AWR Office and showed fairly good agreement [7]. The interface is extensive, but user-friendly with a similar menu layout as Genesys and Microwave Office. The output plots and charts are also intuitively straight forward to use. DesignerRF features: linear/non-linear circuit simulation with real-time tuning, optimisation and sensitivity analysis, frequency domain and transient analysis, digital and analogue systems simulation, IC and PCB layout with Java and Visual Basic and a full-wave 3D electromagnetic simulation. Meshing and simulating the full layout is a straight forward procedure. The software benefits from a wide range of parts in its built-in library models, good continuous support is also available from an Ansoft engineer. [8].

DesignerRF, however, has some drawbacks: (1) the manufacturer's parts contain data files for Agilent ADS and MW Office only, which means that an equivalent circuit would have to be constructed to model each device, otherwise a Spice or S-parameter file would have to be used which can limit its accuracy, (2) the cost is high e.g. a commercial licence is, roughly, twice that of AWR MW Office and Agilent ADS for the full range of features.

ADS Agilent [9]: ADS Agilent is a highly extensive and sophisticated piece of software. It contains a variety of bundles, including PLL (phase locked loops) design, time domain and EM modelling (momentum simulator). The range of examples is extensive and also comes with a design guide. However, the interface of ADS was found to be the least user-friendly of the software packages and would, therefore, require plenty of training and practice in order to use it to its full potential. For those used who have mastered the interface of ADS it is a tool with access to an extensive list of vendor libraries, X-parameter and other models providing a detailed and accurate tool for microwave component design.

3   Microwave Computation Software – with partial features

LINC2 (ACS): is a low cost, user friendly linear circuit simulator for microwave components. This will do the basic, but reasonably accurate modelling for microwave components, such as amplifiers, filters, attenuators, oscillators, amplifiers. The modelling is based on the S-parameters of active and passive devices, substrates, microwave transmission lines, attenuators, stubs, gaps, VIA holes etc. It has microstrip, strip line and other high frequency models (including s-parameters) for designing RF, microwave and mm wave circuits. It can plot the magnitudes and phases of the S-parameters, delay, MSG, K, Delta, input and output resistance and impedance, SWR (input and output). It can also plot Smith Charts of input and output impedance, input and output reflection (S11 and S22). As LINC2 is a linear model it cannot simulate non-linear effects, such as, oscillator start-up time, gain compression, noise effects etc. [10]

HSPICE: is a transient (time domain) software by Synopsis. This is only licensed to universities if used as a stand-alone program but HSPICE is incorporated into commercial microwave software such as Ansoft Designer RF and AWR Analogue Office.

Cadence RF Design: is a versatile RF design software suite with many applications and features. Cadence Virtuoso Spectre RF contains a SPICE-level analogue and RF modelling but this software has partial modelling capabilities for high frequency microwave circuit design.

EM Simulation Tools: -

WIPL-D Microwave: a circuit and full-wave 3D electromagnetic simulation for RF and MW applications. This software uses grids to define structures, models edge effects and layered structures. This software is easy-to-use and is capable of modelling 3D structures; however this package is more useful for the physical modelling of passive components such as antennas, filters and resonators, rather than MW simulations of active electronics devices such as transistors, amplifiers and oscillators. The cost of the software is considerably less than the mainstream packages discussed in section 2.

Sonnet: is one of the most popular choices of EM simulation tools for the modelling of passive microwave components. Although Sonnet-lite is a freeware version, it has a range of useful capability enabling the user to design structures and carry out an EM simulation.

IE3D SSD (Zeland software): a 3-D electromagnetic software which employs the method of moments. Rectangular and triangular meshes are used to model arbitrary shaped structures. This EM software can be used to model integrated circuits, components and antennas.

Pedasoft EM-Supreme: a time domain EM field device simulation with S-parameters and large signal analysis.

4 Summary of main features and cost of the featured design software packages

Table 1 (below) outlines the requirements for accurate modelling of microwave design software (shown in the 'features' column) and how these are satisfied by the various microwave design software. There is the option of combining an EM model e.g. Sonnet, with a linear mode LINC2 and HSPICE instead of purchasing a single integrated package. The features of this option are indicated as one of the columns in the table.

features	Agilent ADS	Agilent Genesys	AWR Microwave Office	Ansoft Designer RF	Combine: HSPICE/Sonnet/LINC2	Cadence Spectre RF	WIPL-D Microwave	Pedasoft EM Supreme	IE3D SSD (Mentor Graphics)
Linear, S, Y, Z parameters etc.	✓	✓	✓	✓	✓	✓	✓	✓	
Nonlinear: Harmonic Balance	✓	✓	✓	✓		✓			
2D/3D Layout	✓	✓	✓	✓	✓	✓	✓	✓	✓
EM simulation/ efficient meshing	✓	✓	✓	✓	✓	✓	✓	✓	✓
Examples/tutorials	✓	✓	✓	✓	✓	?		?	?
Transient simulator	✓	✓	✓	✓	✓	✓	✓		
Vendor libraries/ accurate models	✓	✓	✓	✓				?	
Account for all MW components	✓	✓	✓	✓				✓	
Available support	✓	✓	✓	✓		✓	?	?	✓
Relatively low cost		✓			✓	✓	✓	✓	✓
User Friendly		✓	✓	✓	✓	✓	✓	✓	?

Table 1: Comparison of the main features of microwave design software

4.1 A rough comparison of commercial costs

With many commercial commodities an item's quality is based on its price, to some extent this applies when choosing design software for Microwave Engineering. Ansoft DesignerRF is the most costly but has a wide range of facilities that are user-friendly, its cost is nearly double that of AWR's Microwave Office. There is also an annual support and upgrade fee of around 15% of the purchase price for both of these packages. Agilent ADS (basic package and support) is approximately the same cost as AWR Microwave Office (with all features) but ADS support is without the annual fees. The cost of ADS can considerably increase with the number of add-ons to the basic package e.g. the transient add-on will increase the cost by roughly 75%. The low cost option is Agilent Genesys, where Genesys Core is a third of the cost of AWR Office and ADS Agilent (basic) making this a low cost alternative whilst providing suitable design accuracy for microwave components. The add-ons to Genesys e.g. EM and synthesis do increase the cost, but is well below that of the basic costs of the other packages.

5   Conclusions

There have been significant advances in the recent development of modelling tools for microwave component design, in particular with electromagnetic (EM) simulations. Today's software tools employ highly developed models to provide an accurate representation of the microwave devices - including surface mount or chip devices. Depending on the type of component modelled a linear and a nonlinear simulator are normally required, a time domain and EM simulators may also be required.

In this paper, the main software packages for the design of microwave components have been discussed. LINC2 provides a good linear approximation for most components; more sophisticated models are required for nonlinear behavioural modelling. HSPICE is the favoured of the SPICE programs used for transient behavioural modelling. Sonnet (or Sonnet-lite) is also a well known EM solver. These three programs, combined, would therefore provide adequate modelling capability.

The well known, established, providers of integrated design packages are: Agilent, AWR and Ansoft providing the microwave design tools of ADS, Genesys, Microwave Office and DesignerRF. Both DesignerRF and Microwave Office have a wide range of features to provide the capabilities for professional use [7] and they both have user-friendly interfaces. AWR's Office package however is less costly than that of Ansoft's DesignerRF. Agilent provides two software suites: ADS and Genesys (formally an Eagleware product). ADS is more costly and requires a lot of practice, but it does provide excellent modelling precision. Genesys, on the other hand, may approximate some of the small details of the circuitry thus limiting some of its modelling precision. However, as microwave circuit modelling tool, Genesys does provide a good low cost, user-friendly alternative.

References

[1] G. D. Vendelin, A. M. Pavio and U. L. Rohde, *Microwave circuit design using linear and nonlinear techniques*, 2nd Ed., p. 891, John Wiley & Sons, 2005

[2] Jia-Shen G. Hong and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, John Wiley & Sons, 2001

[3] L. W. Nagel and D. O. Pederson, SPICE (Simulation Program with Integrated Circuit Emphasis), Memorandum No. ERL-M382, University of California, Berkeley, Apr. 1973

[4]website:*http://www.synopsys.com/Tools/Verification/AMSVerification/CircuitSimulation/HSPICE/Pages/default.aspx*

[5] website: *http://web.awrcorp.com/Usa/Products/Microwave-Office*

[6]website:*http://www.home.agilent.com/agilent/product.jspx?nid=-34275.0.00*

[7] D. V. Tosic and M. Potrebic, *Microwave Software Tools for Research and Education*, *Microwave Review*, vol. 12, no. 2, pp. 45-54, Nov. 2006.

[8] website: *http://www.ansoft.com/products/rf/designerrf/*

[9] website: http://www.home.agilent.com/agilent/product.jspx?nid=-34346.0.00

[10] website: www.appliedmicrowave.com