

***ECLIPSE* – An affordable microwave circuit analysis program**

INTRODUCTION

The advent of the sub-\$1k Pentium-class PC has revolutionised the way engineers work. Practically every engineer has one of these on his desk at work, or at home, or both. As far as RF and microwave engineers are concerned, the problem is now no longer being unable to afford a PC with adequate computing power but where to find affordable microwave CAD software, and the market for this software is substantial. Such software will be used by engineers at home, by students at college or university, by engineers in small firms, and by engineering consultants. There is even a need for low-cost microwave CAD software in large corporate organisations for performing ‘what-if’ calculations and simplified analyses since it is unrealistic to provide every RF and microwave engineer with a UNIX workstation and high-end microwave CAD software due to the huge cost involved. In an ideal world the PC-based software would be able to perform both linear and non-linear analysis and optimisation. Electromagnetic analysis would be a welcome addition, and compatible file formats between the PC and UNIX software would be a real godsend. However, the requirement that the cost of the software be similar to that of the hardware inevitably means that compromises have to be made in the facilities available in the software.

NEW FEATURES

Eclipse from Arden Technologies, Inc. is a program capable of fulfilling, at least partially, some of the objectives listed above. Arden Technologies has recently released version 5 of *Eclipse* which, unlike the preceding version, is now a full 32-bit program that requires the Windows™ 95/98 or NT operating system. A pentium CPU, 8MB of RAM, 5MB of hard disk space, and a SVGA monitor are also required. Version 5 costs \$695 until 1st August, but an upgrade from version 4 can be obtained for \$199. The full software can be downloaded from the company’s web site www.ardentech.com and evaluated free for 30 days.

The user interface, shown in Figure 1, is virtually unaltered from the preceding version and it remains a model for all other circuit simulators to emulate. The circuit is entered via a traditional net-list. Pressing F2 brings up an Element Assistant that prompts the user with the data fields for each element and context sensitive help is available for all parameters. *Eclipse* net-lists cannot, however, be directly imported into other simulators due to the different formats used. As an example, *Eclipse* uses TLE to define an ideal electrical transmission line whereas Touchstone™ uses TLIN. Since net lists are simple ASCII files, it would be very simple to write a macro in a word processor to automatically convert *Eclipse* files into other formats.

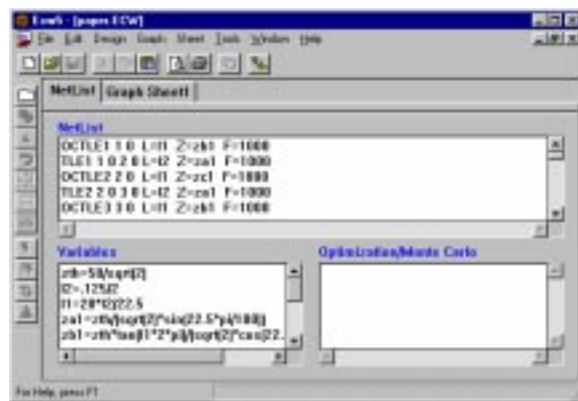


Figure 1. User Interface

Available circuit elements include all the expected lumped elements such as resistor, capacitor, inductor, ideal transformer, voltage controlled current and voltage sources etc. Transmission line elements include microstrip single and coupled lines, stripline, and coax as well as ideal electrical or physical transmission lines. Blackbox elements can also be included, either via a set of *S* parameters or via some of the built-in elements such as an ideal attenuator, amplifier, or delay block. Measurements that can be made on a circuit include *S*, *Y*, *Z* parameters, maximum available gain, group delay, and stability factor. Unusually, *Eclipse* provides the single parameter μ , the Edwards stability factor, to determine unconditional stability as well as the more traditional two parameter terms *K* and Δ .

Stability and constant gain circles can also be displayed. Other related measurements include the calculation of series/shunt port terminations necessary to achieve unconditional stability.

Version 5 has many enhancements compared with the preceding version as detailed in Table 1.

Eclipse is a budget simulator and, therefore, one must expect it to have some limitations. Chief among these is that the program cannot be used for a noise analysis, but this omission will surely be eliminated in a future update. Other limitations include the absence of schematic capture, but this is only an inconvenience rather than a serious handicap. Also, only one port statement can be included in the net-list, which means that sub-circuits cannot be defined. This makes circuits such as distributed amplifiers more tedious to define in the net list, but again this is only an inconvenience, it does not prevent *Eclipse* from being used to analyse and optimise such circuits. The single port statement also has implications for the way that the user handles multiple networks in the same net-list. A common requirement is to compare the performance of two networks on the same graph (e.g. measured and modelled S parameters). This can still be done with *Eclipse* thanks to the increase in the number of ports allowed to 9, and the second example below illustrates how this can be implemented.

Feature	Version 4	Version 5
Number of ports	4	9
Number of nodes	35	unlimited
Number of frequencies	100	2000
Number of open projects	1	Unlimited
Monte Carlo yield analysis	No	Yes
Constant gain circles	No	Yes

Voltage at any node as output parameter	No	Yes
Multiple design versions within a single project	No	Yes

Table 1 Enhancements in Version 5

Although *Eclipse* is a budget simulator, it has several features normally found only in high-cost professional programs. These features include element sweeps, parameter sweeps, and the ability to form user variables. The parameter sweep feature is illustrated in the first example below. Parameter sweeps and user variables both make use of the very comprehensive mathematical function capability that is built into *Eclipse*.

Another high-end feature, introduced for the first time in version 5, is the inclusion of Monte Carlo yield analysis. Monte Carlo analysis allows the user to investigate the performance of the circuit when the values of selected circuit elements or other parameters such as dielectric constant, substrate thickness etc. have a normal (Gaussian) or uniform distribution around their intended value. This enables the user to estimate the production yield of the circuit based on the component tolerances. While *Eclipse* allows the user to determine the effect of component tolerances on performance, it does not allow the effect of spreads in transistor S parameters to be evaluated. One criticism often levelled at the Monte Carlo technique is that it doesn't evaluate yields in a realistic manner in some situations. For example, in a microstrip coupler the width and separation of the lines do not vary randomly. In reality, the parameter that varies is the undercut in the etching process with the result that increased separation of the lines is accompanied by decreased width. This effect can still be handled in *Eclipse* using the variable facility to define width as a function of separation and then to apply a Monte Carlo analysis to just the separation of the lines.

EXAMPLES

The first example is a varactor-tuned filter with the varactor's capacitance described as a function of applied voltage as shown in Figure 2. The response of the circuit can then be plotted as a function of applied voltage as shown in Figure 3 using the parameter sweep facility.

```

Net List
C1 1 2 C=CAP
L1 1 2 L=100
PORT 1 2

Variables
// DEFINE VARACTOR EQUATION
PHI=0.5
GAMMA=0.5
C0=75 //ZERO BIAS CAPACITANCE
VOLTAGE=5 //APPLIED VOLTAGE
CAP=C0/(1+VOLTAGE/PHI)^GAMMA
    
```

Figure 2 Netlist for varactor-tuned filter

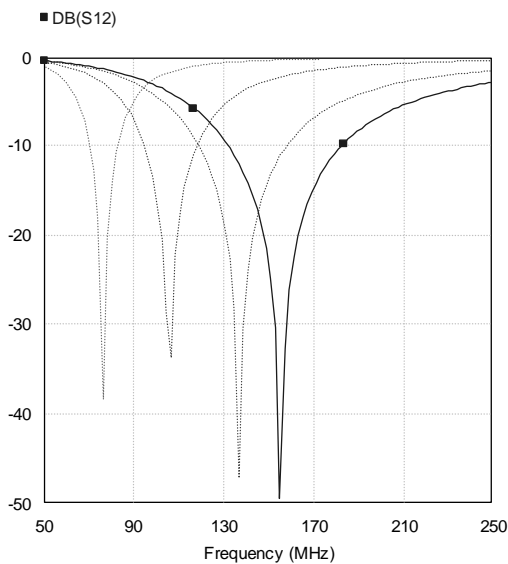


Figure 3 Parameter sweep facility

The second example illustrates the user-defined variable facility and how one can compare the performance of two separate circuits within one net list using the enhanced number of ports available in version 5 of *Eclipse*.

Figure 4 shows a modified rat-race coupler that has an exact 180° phase difference at all frequencies between the outputs at ports 2 and 4 if a signal is applied to port 1. To prove this point, you need to create the user-defined variable $|\angle S_{12} - \angle S_{14}|$ and plot this versus frequency. To compare the performance of this modified rat-race coupler with that of a conventional rat-race, an 8-port network will be defined as shown in the net list print-out in Figure 5. Note that there are two completely separate rat-race couplers within the net-list that are defined by the 8-port network. Figure 6 shows how to compare the phase difference performance of these two independent rat-race couplers using the same graph.

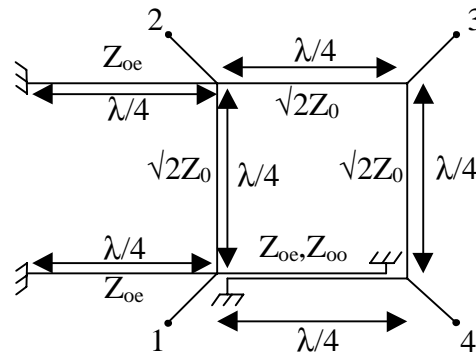


Figure 4. Modified rat-race coupler

```

Net list
SCTLE1 1 0 L=0.25 Z=100 F=10
TLE1 1 0 2 0 L=0.25 Z=70.71 F=10
SCTLE2 2 0 L=0.25 Z=100 F=10
TLE2 2 0 3 0 L=0.25 Z=70.71 F=10
TLE3 3 0 4 0 L=0.25 Z=70.71 F=10
CLINE1 1 0 0 4 L=0.25 F=10
ZO=26.12 ZE=100

TLE4 5 0 6 0 L=0.25 Z=70.71 F=10
TLE5 6 0 7 0 L=0.25 Z=70.71 F=10
TLE6 7 0 8 0 L=0.25 Z=70.71 F=10
TLE7 8 0 5 0 L=0.75 Z=70.71 F=10

PORT 1 2 3 4 5 6 7 8
    
```

Figure 5. Two independent networks within one netlist

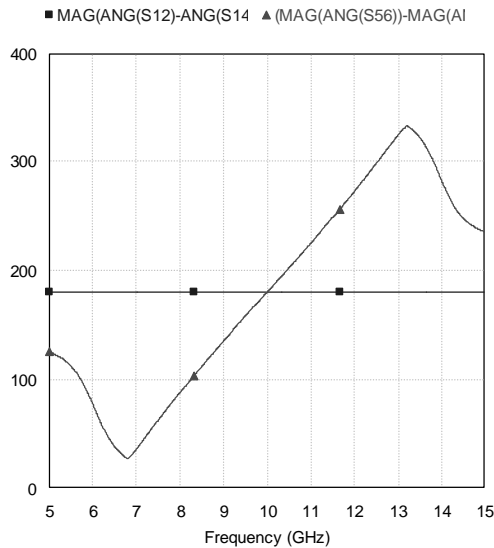


Figure 6. Use of user-defined variable facility

The final example concerns the design of a microstrip coupler to provide 6 ± 0.5 dB coupling over 1-2 GHz. Figure 7 shows the netlist of a coupler that meets this specification.

```

Net-List
MSSUB1 E=9.9 H=15 T=.2 &
C=1000
MSCL1 1 2 4 3 W=w1 L=800 &
S=s1
port 1 2 3 4

Variables
s1=.7{tn 5}
w1= 6.2 {tn 5} !first scenario
w1=6.2-2*(s1-0.7) !second scenario

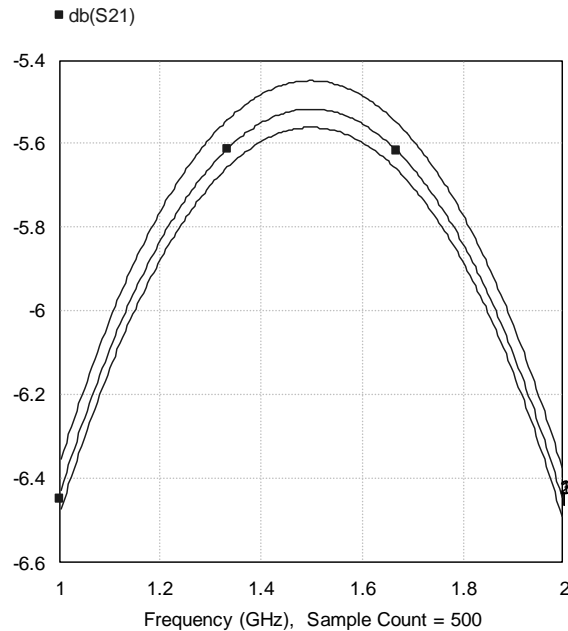
Optimisation/Monte Carlo
points 1
db(s21) ~-6 .5
points 1.5
db(s21) ~-6 .5
points 2
db(s21) ~-6 .5

ypoints 1
db(s21) ~-6 .5
ypoints 1.5
db(s21) ~-6 .5

```

Figure 7 Netlist for Monte Carlo example

The line width and separation are 6.2 and 0.7 mils, respectively, for a 15 mil thick alumina substrate. In practice the line width and separation will vary from these dimensions due to variations in the etching process. Suppose that the variations in track dimensions have a



Sample Count: 500

Freq (GHz)	Param	Goal	Failed	% of Sample
1	db(s21)	~ -6 .5	0	0.00
1.5	db(s21)	~ -6 .5	207	41.40
2	db(s21)	~ -6 .5	1	0.20

Total Param Failures: 208 (41.60%)
 Units with Multiple Failures: 0 (0.00%)
 Total Unit Failures: 208 (41.60%)

Figure 8 Yield analysis of coupler when both width and separation of the lines vary randomly

Gaussian distribution with a maximum variation of $\pm 5\%$ from the intended value at 3 standard deviations away from the mean. The Monte Carlo facility in *Eclipse* enables the effect of this random variation on the performance of the coupler to be determined, and hence the manufacturing yield to be predicted, by calculating the performance of the circuit a large number of times with random perturbations made to the dimensions. The random variations are of course subject to the distribution previously specified. In this particular example, the calculations were performed 500 times for two different

scenarios. In the first, it is assumed that the width and separation can both vary randomly, and Figure 8 shows that *Eclipse* predicts a yield of only 41.6% in this case, the major problem being that the coupling becomes too tight at band centre. In the second scenario, it is assumed that increased separation is accompanied by decreased width, as discussed previously, and the tolerance analysis is applied only to the separation with the associated width being determined via the user-defined variable facility as shown in Figure 7. In this scenario *Eclipse* predicts a significantly higher manufacturing yield of 53.8%. Obviously, the calculations can be repeated with different tolerances to determine what value is needed to achieve an acceptable yield.

CONCLUSIONS

Readers looking for a Windows-based, easy to use yet powerful circuit analysis program would do well to consider *Eclipse*. Version 5 has several significant enhancements over the preceding version that makes this a very powerful linear circuit analysis and optimisation program.

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