MIDAS
A NEW MICROWAVE/RF CAD PROGRAM

David Rhodes and Stewart Perlow

RCA Laboratories
Princeton, NJ

Abstract

A new software CAD tool entitled MIDAS has been developed for microwave/RF network design. MIDAS allows use of algebriac expressions to define any value necessary for network analysis. In addition, any expression may be frequency-dependent. MIDAS is fully integrated with PLANA[1], a network measurement program, allowing PLANA networks to be sub-networks of MIDAS. New component models may be entirely expressed in MIDAS language, alleviating the need to program in other languages.

Introduction

MIDAS includes many features not currently found in microwave/RF circuit design programs. It supports general multiport nodal-network analysis[2] using a modular and expandable component library. Networks are created through the definition of components and their connections. MIDAS allows the definition of any value necessary for network description through general algebraic equations[3], providing an extremely powerful and natural method for defining network parameters and their interdependencies. The multiport outputs may be expressed as algebraic expressions or functions of any network parameter. This allows the user to create output parameters.

The circuit elements consist of all standard types of elements with special emphasis on microwave circuit elements in microstrip and stripline. A unique feature consists of the description of arbitrary arrays of coupled transmission lines by physical parameters. This allows the user to construct circuits containing any number of coupled lines with individual line widths, spacings and terminations. This feature makes analysis and optimization of comb-line and interdigitated geometries very simple.

Extensive error detection is used throughout the program to inform the user of incorrect input information. Errors detected by the program include inappropriate parameter dimensions, improper syntax, incorrect or insufficient parameter specification and erroneous element connections.

The user interface includes full type-ahead and help at every question in addition to allowing user-defined macros[4]. The complete help facility aids inexperienced users, while experienced MIDAS users may take advantage of macro commands.

Circuit Description

One of MIDAS' key features is its Network Descriptive Language (NDL). The MIDAS NDL is organized as a collection of non-procedural statements. The term non-procedural means that there is no sequential information associated with the language. Thus the MIDAS NDL fragments (fragments are not complete examples) depicted in Figures 1a and 1b are identical. Simple lumped components, RLC, are defined using simple equations.

```
Rx = 50
R1 = Sqrt(Rx) Ohms
Ry = 25
R2 = Rx - Ry nH
```

Fig. 1a

```
R1 = Sqrt(Rx) Ohms
R2 = Rx - Ry nH
Rx = 50
Ry = 25
```

Fig. 1b

Figure 1. Two Instances of MIDAS language fragments that are identical. Variables may be defined top-down or bottom-up. Notice that MIDAS is upper and lower case independant (see text).

Note that R1 and R2 are typed variables in the sense that they have the dimensions `ohms' and `nH', but that Rx and Ry are not dimensioned and are un-typed. Typed variables may be CONNECTED to form a topology, whereas un-typed variables are used only to define other variables.

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1 *PLANA is an RCA developed two-port measurement program which provides high level control for an HP-8409 network analyzer. PLANA is a registered trademark of RCA Corporation.*

2 *Current work includes statistical analysis and optimization.*

3 *which may be frequency-dependent.*

4 *Macros allow the user to define a names 'set of commands' which can be activated using only the macro name.*

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The typed statements shown in Figure 1 are ideal for defining the lumped elements (resistors, capacitors and inductors), but are not sufficient for defining more complicated components. Components such as transmission lines, coupled transmission lines, discontinuity elements, etc. require multiple parameters in order to define them. The MIDAS language mechanism for doing this is a function statement. An example is shown in Figure 2. T1 is the component described by the Electric Function (or EF) TRL and its associated parameters, Zo, EL, and Cf.

T1=TRL(Zo=50 ohms, EL=90 deg, Cf=2GHz)

Figure 2. A simple transmission Line Example.

This type of syntax is desireable for several reasons. First note that the parameters are explicitly shown, such as "Zo = 50 ohms". This allows MIDAS to accept them in any order. The langauge element "Zo" is termed an Electric Function Parameter (or EFP).

The MIDAS component library is quite extensive (and will be expanded). This makes it prohibitive to present in this paper, however, Figure 3 presents current component list.

Figure 3 lists EF and possible parameters, but does not indicate the required parameter combinations. In general each EF has multiple parameter sets which represent a physical situation (or idealized electrical situation). All of these parameters need not be specified. As an example, the idealized transmission line has sixteen possible parameter sets. Again, describing the parameter sets for all of the EFs would be much to voluminous for this report.

Any of the numerical parameter values used as EFPs may be algebraic expressions. Indeed, MIDAS NDL structure allows the use of equations to define any value, including those defining EFP values. In addition to defining values through the use of equations of other variables, MIDAS allows frequency dependency. Figure 4 depicts this, showing electrical length (EL) as a frequency dependent value.

The characters ´FREQ´ (as in Figure 4) represent frequency in MIDAS. This is a unique feature of MIDAS, no other linear CAD program allows such liberal use of equations, and the arbitrary use of frequency dependent variables.

The dimensions for the parameters may be expressed in any of the conventional forms. MIDAS will automatically scale values to those suitable for its internal code structure. As an example, the physical length of a transmission line may be expressed in inches while its width is expressed in millimeters.

ELEMENT TYPES **PARAMETERS**

IMPEDANCE
- Characteristic Impedance
- Real Part (resistance)
- Imaginary Part (reactance)

ADMITTANCE
- Characterisitic Admittance
- Real Part (conductance)
- Imaginary Part (susceptance)

TRANSMISSION LINES
- Media Type:
  - General Electrical
  - Microstrip
  - Stripline
  - Coaxial
  - Rectangular waveguide
- Characteristic Impedance
- Characteristic Admittance
- Physical Length
- Electrical Length
- Loss-dB/meter
- Attenuation-dB/wavelength
- Relative Dielectric Constant
- Copper Loss
- Loss Tangent
- Width of Strip
- Height of Substrate
- Diameter of Conductor

COUPLES TRANS LINES
- Media Type:
  - Microstrip
  - Stripline
- Physical Length
- Electrical Length
- Height of Substrate
- Width of Strips (can be unequal)
- Separation of Strips (can be unequal)
- Number of Strips
- Relative Dielectric Constant

GYRATOR
- Gyrostatic Coefficient

IDEAL TRANSFORMER
- Transformation Ratio

DEPENDENT CURRENT GEN
- Complex Transfer Admittance (current gain)

Figure 3. A list of MIDAS Electric Functions (EF) and their parameters (EFPs) with no indication of the proper combinations.

T1=TRL(Zo=50 ohms, EL=90–SQRT(FREQ) deg, Cf=2 GHz)

Figure 4. A transmission Line example illustrating the use of frequency dependant values.

The environment specifications allows any set of EFPs to be collected and specified only once. Many times the electrical components in a given network share a common set of parameters (for example, all transmission lines are on microstrip, and may have a common height and dielectric constant).

Connections

Connections are specified using nodal notation. The node connection numbers may be specified on the same line as the component definition. In the case of several network components having the same definition but different connections, the component may be specified on one line and the connections written on a line containing the name of the component and the node numbers.

Outputs

Built into MIDAS are all the standard outputs offered by linear CAD programs. MIDAS allows not only these standard outputs, but equations based upon these outputs at any network port. Since network outputs are generally complex-valued, MIDAS computes complex values when computing output values.

Sub-Networks and Sub-Models

MIDAS allows any network to be considered as a sub-network. This may be another MIDAS network or a measured network (from PLANA). An example is shown in Figure 5.

```
S1 = :SUBNET/1 2 3/
```

Figure 5. S1 becomes a representation of the subnetwork called SUBNET. Nodes 1, 2, and 3 are able to be accessed in the current network.

The ability to allow sub-networks is not unique, but MIDAS embodies several major improvements on this concept. Any sub-network may be analyzed or optimized independently. MIDAS networks may be specified as being TABULATED; tabulated networks are not specified as components and connections but rather as an enumerated set of data. This data may be in any form that fully describes the network such as S-, Y-, or Z- parameters. Automated measurement systems provide network information in this way. In particular, MIDAS will also be fully integrated with RCAs PLANA program. This will allow network designers to mathematically encorporate any device or circuit in their designs which is measured with PLANA. MIDAS treats PLANA data in the same way it treats its own tabular type data.

As a further extension to sub-networks, MIDAS allows the user to define MODELS. Models in MIDAS are sub-networks which have parameters passed to them. An example of a MIDAS NDL fragment illustrating this is shown in Figure 6.

```
Network: MAIN
   ***
  X1 = 50*SQRT(FREQ)
  X2 = 45
  S1 = :SubModel( X1, 2*X2, 10 )/1 2/
   ***
 END
NETWORK: SubModel( x,y,z )
    "Use x,y,z to define SubModel"
END
```

Figure 6. A MIDAS language example illustrating MODELING. Note that the MIDAS subnetworks can be considered models with no passed parameters.

Whenever a network has parameters passed to it, it is considered a 'MODEL'. Notice that sub-networks can be considered as parameter-less models. From MIDAS' point of view the only difference between models and sub-networks is that models cannot be analyzed independently of some other network.

This modelling concept is extremely useful in circuit design and component modelling, and is unique to MIDAS. With this capability, many custom components could be modelled instead of necessitating the addition of an internally coded component. Thus any network that can be constructed by MIDAS components and other sub-models can be simulated.

Example

The example shown in Figure 7 displays many of the features of MIDAS. The network represents a coupled transmission line 3 dB coupler similar to the Lange coupler. This example shows the effect of changing the position of the bond wires, and lengths of line, from their values in the symmetrical case. The network consists of two sets of four coupled lines, 't1' and 't2'. Note that all the line parameters except for the electrical length are specified as environments, 'ev1' and 'coupev'. The only difference between 't1' and 't2' is their electrical lengths. The equations defining their electrical lengths, 'len1' and 'len2' indicates that their sum is always 90 degrees but as 'P1' is changed from 0 to 1, the length of 't1' will grow while the length of 't2' diminishes by the same amount.

The elements called 'bridge' represent bond wires which are defined once as 0.13 nH, but connected in five separate locations. Similarily, 'printed' represents the printed transmission lines connecting the ends of the coupled lines.

Port definitions consist of two sets of numerical parameters. Port #1 which appears between nodes 1 and 9 of the main network are connected to nodes 1 and 2 of a load.

The outputs are defined by equations. `Out1´ is defined as the polar form of S11, where the operator `rtop´ converts the rectangular value of a complex number to polar form. `Direct´ is defined as S21 in dB, where the operator dB converts the magnitude of its argument to dB. `Difference´ is defined by the equation which subtracts the value of the output `coupled´ from the value `Direct´.

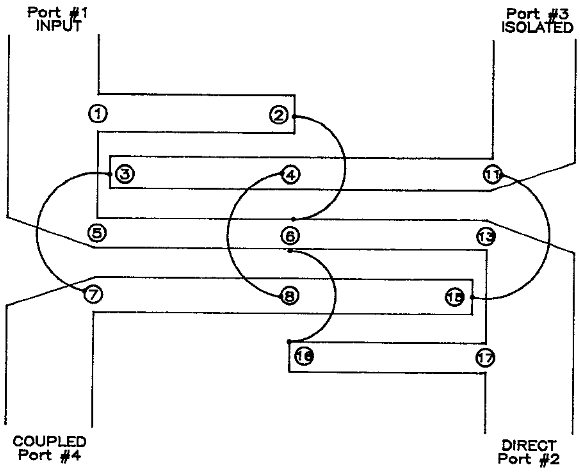

Figure 7a. A Network

```
Logical
Line

  1   Network: Lange6
  2     FREQUENCIES:
  3       10 20 1 ghz
  4     PORTS:
  5       #1    1 9
  6       #2   17 9
  7       #3   11 9
  8       #4    7 9
  9     ENVIRONMENT:
 10       ev1     : ms, ht=20mils, wt=1.5 mils, er=10
 11       coupev : sep=1.6 mils, cf = 15 GHz, num =4
 12     COMPONENTS:
 13       P1       = 0.2 [ 0.1, 0.9, 0.1 ]
 14       Tlen     = 90
 15       len1     = p1 * Tlen
 16       len2     = (1 - p1) * Tlen
 17       bridge = .13 nH
 18       t1=coupled(env=ev1,env=coupev,el= len1 deg)
 19       t2=coupled(env=ev1,env=coupev,el= len2 deg)
 20       printed = trl(env=ev1, pl=5 mils)
 21     CONNECTIONS:
 22       t1 1  2  3  4  5  6  7  8 9
 23       t2 4 11  6 13  8 15 16 17 9
 24       printed  1  5  9
 25       bridge   3  7
 26       bridge   2  6
 27       bridge   6 16
 28       bridge  11 15
 29       printed 13 17  9
 30       bridge   4  8
 31     OUTPUTS:
 32       out1=rtop(s11)
 33       out2=rtop(s22)
 34       out3=rtop(s44)
 35       Direct     = dB(s21)
 36       Coupld     = dB(s41)
 37       Isolated = dB(s31)
 38       Difference = Direct - Coupld
 39       PhaseDif     = phase(s21)-phase(s41)
 40>    END
```

Figure 7b. MIDAS Representation

```
******************** Output Definitions ********************

Output  1 is:    32      out1=rtop(s11)
Output  2 is:    33      out2=rtop(s22)
Output  3 is:    34      out3=rtop(s44)

     ******************** Results ********************

Freq(MHz)           1                   2                   3
10000.000    0.046   73.538     0.019   25.751     0.021  104.583
11000.001    0.052   72.059     0.020   25.059     0.026  103.926
12000.000    0.058   70.218     0.021   23.650     0.031  101.947
13000.001    0.064   68.075     0.021   21.076     0.035   99.172
14000.000    0.071   65.683     0.022   17.043     0.040   95.908
15000.001    0.077   63.086     0.023   11.341     0.044   92.337
16000.000    0.084   60.320     0.024    3.754     0.048   88.576
17000.000    0.091   57.406     0.025   -5.992     0.051   84.709
18000.002    0.098   54.360     0.026  -18.224     0.053   80.819
19000.000    0.105   51.186     0.027  -33.191     0.054   77.018
20000.000    0.112   47.879     0.030  -50.787     0.054   73.487

******************** Output Definitions ********************

Output  4 is:    35      Direct     = dB(s21)
Output  5 is:    36      Coupld     = dB(s41)
Output  6 is:    37      Isolated = dB(s31)
Output  7 is:    38      Difference = Direct - Coupld
Output  8 is:    39      PhaseDif     = phase(s21)-phase(s41)

     ******************** Results ********************

Freq(MHz)     4         5          6          7         8
10000.000   -2.431    -3.705    -34.526     1.274   -92.092
11000.001   -2.637    -3.449    -33.697     0.812   -92.299
12000.000   -2.801    -3.266    -32.966     0.465   -92.504
13000.001   -2.920    -3.144    -32.309     0.224   -92.706
14000.000   -2.994    -3.077    -31.707     0.083   -92.906
15000.001   -3.020    -3.059    -31.147     0.039   -93.101
16000.000   -3.000    -3.091    -30.621     0.091   -93.292
17000.000   -2.932    -3.172    -30.120     0.241   -93.478
18000.002   -2.818    -3.309    -29.640     0.491   -93.657
19000.000   -2.660    -3.509    -29.174     0.849   -93.827
20000.000   -2.460    -3.783    -28.716     1.323   -93.985
```

Figure 7c. Output Listing

In Conclusion

MIDAS not only embodies many very-advanced features, but also allows the user simple and intelligable use of them. The MIDAS NDL was carefully planned and implemented to provide simple, but extremely powerful capabilities. The currently implemented component models (the EFs) are the most up to date available. But the MIDAS language and program structure encourages expansion and exploration of new models. The modular interface between the main program and its models, and especially the modelling capabilites of MIDAS will help keep it current.