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MENU DRIVEN FULLWAVE ANALYSIS OF MICROSTRIP DISCONTINUITIES USER MANUAL

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Menu Driven Fullwave Analysis of Microstrip Discontinuities
User Manual

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1 Preface

This user manual provides the necessary background to run successfully the FORTRAN codes written by William Harokopus for the study of high frequency microstrip elements. The codes are menu driven and provide answers in the form of scattering parameters for 1, 2, 3 , and 4-port elements. The codes were developed during the period from Jan. 87 and September 91.

2 Introduction

The Numerical codes discussed in this report were developed from the Space Domain Integral Equation Technique. This technique has been used extensively for the study of microstrip structures and is believed to be very accurate. This is particularly true in the study of very high frequency components. Information on the technique and its application to microstrip may be obtained in the publications by Harokopus and Katehi.

The menu driven programs are designed to operate in two phases. The first phase evaluates coupling interactions resulting from the method of moments treatment. This phase requires knowledge of the substrate parameters, the discretization size, the mesh size, and the frequency. Phase two solves for 1,2,3 or 4-port scattering parameters and therefore requires more precise information concerning the dimensions of the particular discontinuity being studied. The programing was divided into these two stages for two reasons which are:

- The first is that phase one can be far more time-consuming than phase 2.
- The results from phase one are re-usable for different structures or dimensions

The following sections demonstrate correct menu operation, show how to compute discretization and mesh parameters, and provide several examples including final results. A basic knowledge of microwave terminology and convention is assumed.. A listing of program names and locations on the CAEN network is given in appendix A.

3 Interactive Menu

3.1 Phase I

After running phase 1 (entitled s2main.ftn), the user is prompted for various parameters concerning the substrate, and mesh size. A listing of the variables involved includes F(operating frequency),TD(metallization thickness), T2(substrate height), dlx, and dly (length and height of discretization), nxn and nym (integer size of mesh), and FI(output file for impedance matrix vector). The units for many parameters may be entered in mm, mils, or free space wavelengths. After entry of all parameters a table is printed as shown below:

```
ne of geometry configuration file      [NAME] ma50.fmt

ostrate rel. dielectric constant;   [ER]:         10.0000

MENSIONS NORMALIZED TO FREE SPACE WAVELENGTH
MENSION ENTRY IN MILS     : CHANGE UNITS [CU]     normalized        (mils)        (millimeters)
                                                  ----------       --------        -----------
equency (GHz) of operation  (lambda_o)  [F]      50.0000000  (    236.0570831)  (  5.9958496
ickness of metallization               [TD]       .0211813  (     5.0000000)  (    .1270000)
ickness of metallization                [T2]       .0000424  (      .0100000)  (    .0002540
ngitudinal subsection length           [DLX]       .0105907  (     2.5000000)  (    .0635000
ansverse  subsection length            [DLY]       .0105907  (     2.5000000)  (    .0635000
rmalized longitudinal mesh length;    [nxn]:        60
rmalized transverse mesh width;       [nym]:        60
ta file for admittance matrix           [FI] meand50.out

nter Variable Name [**] or <return>
```

Incorrect entries may be corrected by entering the desired variable shown in parantheses and typing the new value when prompted.

3.1.1 Determining Discretization Size

This version of the program allows for only a square discretization size(dlx=dly). The discretization should be made with two considerations in mind. The first is to have a grid size which is has no fewer than 25 and no more than 80 subsections per guide wavelength. Using less than 25 will compromise accuracy, and using more than 80 will make the number of unknowns too large. In general 30-40 is the optimal range. The second consideration is choosing a grid size which conforms to the dimensions of the discontinuity(s) to be simulated. Dimensions of the structure must be multiples of the grid size.

3.1.2 Determining Mesh Size

The parameters [nxn] and [nym] are the integer length of the mesh in the x and y directions. The total size of the mesh is obtained by multiplying these parameters by the discretization size. The mesh must be at least as large as the discontinuity and its corresponding feeds. For square discretizations the mesh must be square(nxn=nym).

3.2 Phase II

Phase II enters the intermediate results(impedance vector) from phase I , fills a matrix according to dimensions and structure type designated by the user, solves the matrix, and provides results in [s]-parameter form.

After execution of the program [m4pdisc.ftn], the program prompts the user for the configuration file name:

Enter name of configuration data file;

The user enters the configuration file generated from phase 1. The program then asks for the number of ports:

```
Select number of ports:
[1] 1-port
[2] 2-port
[3] 3-port
[4] 4-port
```

After selection of the number of ports the program enters sub-menus to determine the discontinuity to be analyzed. For example a mitered bend simulation would appear:

```
[1] right angle
[2] mitered
[3] optimally mitered
```

The program then requires the dimensions of the bend. All simulations also require the effective dielectric constant which must be determined in advance from touchstone or other 2-D simulations. After entry of this data a menu is printed to the screen:

```
ame of geometry configuration file     [NAME] ma70

over rel. dielectric constant;  [ER]:        10.0000

IMENSIONS NORMALIZED TO FREE SPACE WAVELENGTH
IMENSION ENTRY IN MILS     : CHANGE UNITS [CU]     normalized       (mils)        (millimeters)
                                                   ----------      --------       -----------
requency (GHz) of operation  (lambda_o)    [F]      70.0000000  (   168.6121979)  (  4.2827499
hickness of cover                         [TD]      0.0296538  (     5.0000000)  (  0.1270000
hickness of metallization                 [T2]      0.0000059  (     0.0010000)  (  0.0000254
ongitudinal subsection length            [DLX]      0.0148269  (     2.5000000)  (  0.0635000
ransverse  subsection length             [DLY]      0.0148269  (     2.5000000)  (  0.0635000
idth of line                              [WW]      0.0148269  (     2.5000000)  (  0.0635000
ength of feed line                       [XLL]      0.4448077  (    75.0000000)  (  1.9050000
ffective dielectric constant              [XK]      6.6999998
ormalized longitudinal mesh length;      [nxn]        60
ormalized transverse mesh width;         [nym]        60
ata file for admittance matrix            [FI] meand70


Enter Variable Name [**] or <return>
```

The user may re-enter incorrect parameters at this point. He may not change parameters which were set in phase 1. After returning the program will run and in several seconds to several minutes the answer will be printed to the screen. In the case of a T-junction for example:

```
PERFORMING BACKSUBSTITUTION(even)
PERFORMING BACKSUBSTITUTION(odd)
PERFORMING BACKSUBSTITUTION(3)
S( 1 1) 0.3017638 166.4064
S( 1 2) 0.6937661 -11.21025
S( 1 3) 0.6458406 2.621903
S( 2 1) 0.6937646 -11.21055
S( 2 2) 0.3017560 166.4059
S( 2 3) 0.6458471 2.621877
S( 3 1) 0.6474022 2.526864
S( 3 2) 0.6474065 2.526510
S( 3 3) 0.3877579 194.9552
radiated power= 1.0517158E-02
```

3.2.1 Determining Feed Length

The discontinuity to be tested must be fed by microstrip lines of sufficient length to solve for input impedances and subsequently network parameters. It has been determined that sufficient length should be at least 1 guide wavelength(λ_g). The guide wavelength is determined by the effective dielectric constant(ϵ_{eff}) which can be obtained from Touchstone data, or two-dimensional simulations by Norm Vandenberg (To be integrated into the package). The length of line required is then:

$$L_{feed} = \lambda_g = \frac{c}{f * \sqrt{\epsilon_{eff}}} \qquad (1)$$

appendix A-Program Listing

The menu driven fortran programs are located in the directory:
//xenia/users/harokop/exit_dir/microstrip_dir
To accomplish phase 1 of the procedure the program "s2main.ftn" is used. For the multilayer cases The programs "supmain.ftn"(binded with "spint.ftn") and "tlayer.ftn"(binded with "spint.ftn") run phase 1. In order to run phase 2 and find the scattering parameters the program "m4pdisc.ftn" (binded with "linpack.ftn") must be run.

Also included in the above directory are the intermediate results from phase 1 for the example shown in appendix B. The format and output files are entitled ma30-ma100 and meand30-meand100 respectively.

appendix B-Example of Phase 1

In this appendix a complete run for to create ma50 and meand50 is reproduced.

```
.in
.er name of configuration data file;
)
:ER FREQUENCY (GHz):

ITRIES NORMALIZED TO FREE SPACE WAVELENGTH? ( <return> = yes ):

.ect units:
| MILS
| mm

MENSIONS ARE TO BE ENTERED IN MILS
:er REAL part of substrate relative dielectric constant :

:er thickness of substrate: (mils)

ter thickness of metal: (mils)
1
ter longitudinal subsection length: (mils)

ter transverse subsection length: (mils)

ter normalized longitudianl mesh size

ter normalized transverse mesh size

ter out file for impedance matrix elements:
nd50

e of geometry configuration file     [NAME] ma50

strate rel. dielectric constant;  [ER]:        10.0000

ENSIONS NORMALIZED TO FREE SPACE WAVELENGTH
ENSION ENTRY IN MILS     : CHANGE UNITS [CU]     normalized      (mils)        (millimeters)
                                                 ----------     --------       -----------
quency (GHz) of operation  (lambda_o)  [F]    50.0000000  (   236.0570831)  (  5.9958496)
ckness of metallization               [TD]      .0211813  (     5.0000000)  (   .1270000)
ckness of metallization               [T2]      .0000042  (      .0010000)  (   .0000254)
gitudinal subsection length           [DLX]     .0105907  (     2.5000000)  (   .0635000)
nsverse  subsection length            [DLY]     .0105907  (     2.5000000)  (   .0635000)
malized longitudinal mesh length;    [nxn]:        60
malized transverse mesh width;       [nym]:        60
a file for admittance matrix          [FI] meand50


ter Variable Name [**] or <return>
```

appendix C-Example of Phase 2

In this appendix a complete run for to solve for the scattering parameters for a single loop meander line is given. This is followed by typical results for the complete sweep of 30-100 GHz for this example.

```
se 2*********

e of geometry configuration file      [NAME] ma50

er rel. dielectric constant;   [ER]:         10.0000

ENSIONS NORMALIZED TO FREE SPACE WAVELENGTH
ENSION ENTRY IN MILS     : CHANGE UNITS [CU]     normalized       (mils)        (millimeters)
                                                 ----------      --------        -----------
quency (GHz) of operation  (lambda_o)    [F]      50.0000000  (   236.0570831)  (  5.995849
ckness of cover                          [TD]     0.0211813  (     5.0000000)  (  0.1270000
ckness of metallization                  [T2]     0.0000042  (     0.0010000)  (  0.0000254
gitudinal subsection length              [DLX]    0.0105907  (     2.5000000)  (  0.0635000
nsverse  subsection length               [DLY]    0.0105907  (     2.5000000)  (  0.0635000
th of line                               [WW]     0.0105907  (     2.5000000)  (  0.0635000
gth of feed line                         [XLL]    0.3177198  (    75.0000000)  (  1.9050000
cing of meander line                      [SM]     0.0423626  (    10.0000000)  (  0.254000
th of line                                [DM]     0.0529533  (    12.5000000)  (  0.317500
ber of periods                            [NP]             1
ective dielectric constant               [XK]     6.5000000
malized longitudinal mesh length;        [nxn]       60
malized transverse mesh width;           [nym]       60
a file for admittance matrix              [FI] meand50


ter Variable Name [**] or <return>

ading impedance vector
00000000000000
00000000000000
00000000000000
00000000000000
.0000000000000
.0000000000000
```

```
4.00000000000000
5.00000000000000
8.00000000000000
0.00000000000000
2.00000000000000
4.00000000000000
6.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
.00000000000000
NNING

sitions of x-current

0
0
0
0
0
0
0
0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
```

```
38 0
39 0
40 0
41 0
42 0
43 0
4 0
5 0
6 0
7 0
8 0
9 0
0 0
1 0
2 0
3 0
4 0
5 0
6 0
7 0
8 0
9 0
0 0
1 0
2 0
3 0
4 0
5 0
6 0
2 -5
3 -5
4 -5
5 -5
6 -5
sitions of y-current

 -4
 -3
 -2
 -1
 0
 -4
 -3
 -2
 -1
 0
RFORMING MATRIX INVERSION

TRIX RECIPROCAL CONDITION =  1.5306330E-04
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 4.0747445E-02  AND MAG[S12] = 0.9879416
G[S11]= 134.5769   AND ANG[S12] = 231.7558
WER RADIATED= 2.2311091E-02
```

ostrate rel. dielectric constant; [ER]: 10.0000

MENSIONS NORMALIZED TO FREE SPACE WAVELENGTH
MENSION ENTRY IN mm : CHANGE UNITS [CU]

		(mils)	(millimeters)
ickness of cover	[TD]	(5.0000000)	(.1270000)
ickness of metallization	[T2]	(.0010000)	(.0000254)
dth of line	[WW]	(2.5000000)	(0.0635000)
acing of meander line	[SM]	(10.0000000)	(0.2540000)
pth of line	[DM]	(12.5000000)	(0.3175000)
nber of periods	[NP]	1	

=20 GHz

ATRIX RECIPROCAL CONDITION = 2.5610888E-04
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 0.1808927 AND MAG[S12] = 0.9005098
NG[S11]= 188.5342 AND ANG[S12] = -53.39265
OWER RADIATED= 0.1563600

:1 GHz

ATRIX RECIPROCAL CONDITION = 1.6047527E-05
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 5.8720998E-02 AND MAG[S12] = 0.9951735
G[S11]= 220.3089 AND ANG[S12] = -49.98627
WER RADIATED= 6.1816573E-03

22 GHz

TRIX RECIPROCAL CONDITION = 3.2087517E-04
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 7.4090175E-02 AND MAG[S12] = 0.9915835
G[S11]= 215.5480 AND ANG[S12] = -53.55463
WER RADIATED= 1.1272788E-02

25 GHz

TRIX RECIPROCAL CONDITION = 1.9552899E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 7.2082400E-02 AND MAG[S12] = 0.9917600
G[S11]= 208.8148 AND ANG[S12] = -61.66417
WER RADIATED= 1.1216342E-02

30 Ghz

TRIX RECIPROCAL CONDITION = 4.0396084E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 7.4191026E-02 AND MAG[S12] = 0.9944218
G[S11]= 195.8359 AND ANG[S12] = -73.45045
WER RADIATED= 5.6208968E-03

=35 GHz

ATRIX RECIPROCAL CONDITION = 1.9900473E-03
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 7.4015193E-02 AND MAG[S12] = 0.9920819
NG[S11]= 181.7664 AND ANG[S12] = -87.64284
OWER RADIATED= 1.0295272E-02

=40 Ghz

ATRIX RECIPROCAL CONDITION = 1.0902056E-04
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 5.9039339E-02 AND MAG[S12] = 0.9884265
NG[S11]= 169.8870 AND ANG[S12] = 259.2616
OWER RADIATED= 1.9527435E-02

15 Ghz

ATRIX RECIPROCAL CONDITION = 3.4132474E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
AG[S11]= 5.5954035E-02 AND MAG[S12] = 0.9912730
IG[S11]= 154.9192 AND ANG[S12] = 245.9838
WER RADIATED= 1.4246881E-02

0 Ghz

TRIX RECIPROCAL CONDITION = 6.8178358E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 5.5380952E-02 AND MAG[S12] = 0.9878620
G[S11]= 138.8215 AND ANG[S12] = 234.7185
WER RADIATED= 2.1061599E-02

5Ghz

TRIX RECIPROCAL CONDITION = 8.2700104E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 4.4583641E-02 AND MAG[S12] = 0.9840499
G[S11]= 124.3158 AND ANG[S12] = 217.9195
WER RADIATED= 2.9658198E-02

7.5
RIX RECIPROCAL CONDITION = 4.8110415E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 3.7729446E-02 AND MAG[S12] = 0.9849458
G[S11]= 118.2313 AND ANG[S12] = 213.5416
WER RADIATED= 2.8458178E-02

60 Ghz

ATRIX RECIPROCAL CONDITION = 3.8664252E-03
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 1.2065395E-02 AND MAG[S12] = 0.9909073
NG[S11]= -30.98552 AND ANG[S12] = 209.2525
OWER RADIATED= 1.7957270E-02

55 GHz
ATRIX RECIPROCAL CONDITION = 5.4558483E-04
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
AG[S11]= 1.6343145E-02 AND MAG[S12] = 0.9883375
IG[S11]= -59.48501 AND ANG[S12] = 189.5378
WER RADIATED= 2.2921979E-02

0 GHz

TRIX RECIPROCAL CONDITION = 3.6973350E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 1.6259484E-02 AND MAG[S12] = 0.9801534
G[S11]= -81.59840 AND ANG[S12] = 179.0910
WER RADIATED= 3.9034903E-02

75 GHz

TRIX RECIPROCAL CONDITION = 1.9371262E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 2.1936961E-02 AND MAG[S12] = 0.9757098
G[S11]= 55.68557 AND ANG[S12] = 161.7494
WER RADIATED= 4.7509134E-02

80 Ghz

TRIX RECIPROCAL CONDITION = 7.2480100E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 4.8603762E-02 AND MAG[S12] = 0.9644873
G[S11]= 36.33909 AND ANG[S12] = 144.8380
WER RADIATED= 6.7402005E-02

) GHz

TRIX RECIPROCAL CONDITION = 7.5945174E-03
RFORMING BACKSUBSTITUTION(even)
RFORMING BACKSUBSTITUTION(odd)
G[S11]= 0.1462795 AND MAG[S12] = 0.9353204
G[S11]= 4.834428 AND ANG[S12] = 110.3224

ER RADIATED= 0.1037779

95 GHz

ATRIX RECIPROCAL CONDITION = 1.1382813E-03
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 0.2516062 AND MAG[S12] = 0.9040772
NG[S11]= -9.004583 AND ANG[S12] = 93.42374
OWER RADIATED= 0.1193387

100

ATRIX RECIPROCAL CONDITION = 9.4958367E-03
ERFORMING BACKSUBSTITUTION(even)
ERFORMING BACKSUBSTITUTION(odd)
AG[S11]= 0.3620355 AND MAG[S12] = 0.8447164
NG[S11]= -24.87141 AND ANG[S12] = 75.18895
OWER RADIATED= 0.1553844