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ABSTRACT

MSTRIP has undergone a succession of improvements since its original publication in 1968. Performance of the 1974 and later versions relating to aspects including weakly coupled (<-30 dB) pairs, low shield heights (closer than substrate thickness), and extremely low-impedance lines will be discussed. A FORTRAN list of the 1978 version is appended.
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I. INTRODUCTION

The "quasi-TEM" numerical analysis of the normal modes of propagation on coupled pairs of microstrip transmission lines named MSTRIP, published by T.G. Bryant and J.A. Weiss in 1968, incorporated a Green's-function representation of "bound charge" at the upper surface of the dielectric substrate. For a wide range of applications, generally those in which the cross-sectional dimensions are small enough relative to wavelength, the accuracy of this method is very good; in fact, results of MSTRIP have been widely cited over the years as a standard for assessment of the accuracy of other microstrip algorithms. MSTRIP has been used, apparently without modification, in commercially available linear circuit analysis packages.

The principal approximations (other than the usual substitution of discrete in place of certain continuous variables) are (a) the quasi-TEM assumption, whereby the results of the analysis are all based on the determination of static capacitance, and (b) the assumption of zero thickness and perfect conductivity of the conductors. Numerous papers have appeared in which this basic analysis has been adopted as the starting point for determination of the influences of dispersive effects and of finite conductivity and thickness of the strips.

The program has had some revisions for improved speed, accuracy, and range of applicability during the years since its original publication. We present this report in order to bring to the attention of microstrip circuit users the current version of MSTRIP and its capabilities and to address some questions which have arisen in relation to recent application requirements.

In 1970 and 1971, an improved program was formulated in which the tabulated dielectric Green's function was replaced by a Fourier-integral evaluation. This change resulted in a very substantial improvement in speed and simplicity, better accuracy, and removal of the limitations on the range of
of substrate dielectric constant values. It also introduced the option of including the influence of a shield, or upper ground plane, above the circuit surface. The geometry of the shielded, coupled pair of microstrip lines is illustrated in Fig. 1. A detailed review of methods and results, with a FORTRAN list of the version of the program then current, was published in 1974. Following some improvements made in 1978, the program name was modified to MSTRIP2. The FORTRAN source of this program is shown in the Appendix.

In more recent times, users have brought up questions relating to the applicability and accuracy of MSTRIP for specific application requirements. Examples: the questions of upper limits on substrate dielectric constant and on strip widths; usability of the program for shielded microstrip with the...
shield very close to the substrate surface ($H_2/H_1 < 2$); the accuracy of the program in cases of very weakly coupled pairs of lines, for which the differences between the two normal-mode characteristic impedances and velocities, which determine the backward- and forward-wave coupling coefficients, are very small.

Applications of these unusual microstrip structures have arisen in various contexts. For example, low-impedance (hence wide-line) transmission lines are needed to match the low impedance of Josephson-junction logic elements in superconducting computers. Low shield heights can be used to correct the even- and odd-mode velocity differences of coupled lines on anisotropic dielectrics such as sapphire. Weakly coupled pairs of lines are used as directional couplers in large time-bandwidth dispersive filters.

In the following sections, information is presented relating to such structures and to some tests of accuracy of the program which their consideration provides.

II. SUBSTRATE DIELECTRIC CONSTANT

Nothing in MSTRIP2 imposes a limit on the substrate dielectric constant $K$. The program has served successfully with $K$ values from 1 to 6000 (in fact, values of $K$ less than unity have been used in order to represent an inverted structure - see Sec.III).

III. APPLICATION TO CASES OF A CLOSELY SPACED SHIELD

For values of $H_2/H_1$ less than 2 (see Fig.1), the gap between the shield and circuit surface is smaller than the substrate thickness. In such cases, MSTRIP2 loses accuracy. For example, with $H_2/H_1 = 1.25$, $S/H_1 = 3.5$, $W/H_1 = 0.50$, and $K = 9.6$ (alumina), MSTRIP2 gives the physically unreasonable result that $Z_{oe} < Z_{oo}$. 

3
<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSFORMATION FROM STANDARD TO INVERSED COMPUTATION IN THE CASE OF A CLOSELY SPACED SHIELD*</td>
</tr>
</tbody>
</table>

Unprimed: Parameters of interest as used in the standard computation (Fig.1).  

Primed: Input/output parameters to be used to analyze the same structure by inverted computation.

\[ R = \frac{H_2}{H_1} \]

MSTRI P Input: \( H'_1 = H_2 - H_1 \)  
\[ \left( \frac{W}{H_1} \right)' = \frac{W/H_1}{R - 1} \]

\[ R' = \frac{R}{R - 1} \]
\[ \left( \frac{S}{H_1} \right)' = \frac{S/H_1}{R - 1} \]

\[ K' = \frac{1}{K} \]

To interpret MSTRI P output, transform tabulated values as follows. (Primed variables are output of the inverted computation, unprimed variables are those of the actual structure of interest.)

\[ K_{\text{eff}} = K' \cdot K \]
\[ Z = \frac{Z'}{\sqrt{K}} \]

\[ C = C' \cdot K \]
\[ V = \frac{V'}{\sqrt{K}} \]

*See Sec.III.
This deficiency may be circumvented by inverting the problem, placing the gap \( K = 1 \) on the bottom, and the substrate \( K > 1 \) above, so that \( H_2/H_1 > 2 \). Because \textsc{mstrip} incorporates the assumption that the gap has a dielectric constant of unity, the input and output parameters must be transformed according to the system shown in Table I.

Using this procedure as a check, it may be verified that \textsc{mstrip2} is accurate to \( H_2/H_1 \) values less than 1.5. For example, for a 50-Ω pair of coupled lines on sapphire with \( H_2/H_1 = 1.5 \), \( S/H_1 = 3.5 \), the two methods agree to within 0.01 percent in impedances and 0.02 percent in velocities. The two agree to within 0.04 dB in backward coupling, even though it is a weak -64 dB. With the shielding height reduced to \( H_2/H_1 = 1.25 \), the discrepancy in impedance between the standard computation and the inverted structure increases to 0.3 percent, unacceptable for the calculation of coupling in this weakly coupled structure.

IV. COMPARISON WITH ANALYTIC CALCULATION

In the special case \( H_2/H_1 = 2 \), the quasi-static electric field in the shielded (coupled) microstrip structure with zero conductor thickness may be shown to be symmetric about the dielectric/air interface. Consequently, the quasi-static characteristics of the microstrip (MS) are identical to those of a balanced stripline (SL) structure of the same dimensions filled with a material of dielectric constant \( K_{SL} = (1/2)(K_{MS} + 1) \).

This equivalency provides a convenient check on shielded microstrip calculations, as analytical expressions for coupled striplines are well known. In Table II are shown the results of calculations for several values of \( S/H_1 \) and \( W/H_1 \), using \textsc{mstrip} and \textsc{mstrip2} for shielded microstrip \( (K_{MS} = 9.6) \) and an analytic approximation for the stripline \( (K_{SL} = 5.3) \). A transcendental approximation valid to 8 parts in \( 10^6 \) compared to the exact elliptic integral expression for stripline impedances was used, given as Eqs.6.3.1, 6.3.2, 3.2.7, and 3.2.8 in the book by Gunston. Both \textsc{mstrip} and \textsc{mstrip2}
### Table II

**Impedance, Coupling, and Effective Dielectric Constant Values**

Calculated by Mstrip, Mstrip2, and Balanced Stripline Methods, \( h_2/h_1 = 2 \); \( K = 9.6 \) for Microstrip, 5.3 for Stripline

<table>
<thead>
<tr>
<th>S/H (_1)</th>
<th>W/H (_1)</th>
<th>( Z_{0e} ) (Ω)</th>
<th>( r_{0o} ) (Ω)</th>
<th>(-k_B) (dB)</th>
<th>((K_{eff})_{even}) (Mstrip)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mstrip</td>
<td>Mstrip2</td>
<td>Stripline</td>
<td>Mstrip</td>
</tr>
<tr>
<td>0.5</td>
<td>0.3</td>
<td>90.29</td>
<td>89.82</td>
<td>89.36</td>
<td>58.26</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>57.72</td>
<td>57.25</td>
<td>56.64</td>
<td>40.60</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>42.94</td>
<td>42.46</td>
<td>42.12</td>
<td>32.43</td>
</tr>
<tr>
<td>1.0</td>
<td>0.3</td>
<td>81.75</td>
<td>81.27</td>
<td>80.81</td>
<td>67.29</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>53.55</td>
<td>53.07</td>
<td>52.65</td>
<td>45.63</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>40.55</td>
<td>40.07</td>
<td>39.70</td>
<td>35.60</td>
</tr>
<tr>
<td>2.0</td>
<td>0.3</td>
<td>76.25</td>
<td>75.77</td>
<td>75.31</td>
<td>72.88</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>50.69</td>
<td>50.22</td>
<td>49.78</td>
<td>48.68</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>38.87</td>
<td>38.39</td>
<td>38.00</td>
<td>37.47</td>
</tr>
<tr>
<td>4.0</td>
<td>0.3</td>
<td>74.87</td>
<td>74.39</td>
<td>73.93</td>
<td>74.27</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>49.96</td>
<td>49.48</td>
<td>49.05</td>
<td>49.42</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>38.65</td>
<td>37.95</td>
<td>37.55</td>
<td>37.91</td>
</tr>
<tr>
<td>10.0</td>
<td>0.3</td>
<td>74.81</td>
<td>74.33</td>
<td>73.87</td>
<td>74.33</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>49.93</td>
<td>49.45</td>
<td>49.01</td>
<td>49.45</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>38.41</td>
<td>37.93</td>
<td>37.53</td>
<td>37.93</td>
</tr>
</tbody>
</table>
were run with $M = 20$ substrips per strip. In addition to the even- and odd-
mode impedances, the backward-wave coupling strength for a quarter-wave
length of line is shown, given by the expression

$$k_B (\text{dB}) = 20 \log_{10} \frac{Z_{oe} - Z_{oo}}{Z_{oe} + Z_{oo}}$$

The even-mode effective dielectric constant given by MSTRIP is also shown.
The odd-mode constant given by MSTRIP and both mode constants given by
MSTRIP2 exhibit the proper value of 5.3.

It is evident that both versions of MSTRIP give reliable impedance and
backward coupling values for $k_B$ in the range of stronger coupling ($S/H_1 < 1,$
$k_B > -25 \text{ dB}$). Impedances are within 1 Ω of the stripline values and coupling
strengths are within 1 dB. In the -30- to -40-dB range ($S/H_1 \sim 2$) MSTRIP2
retains its accuracy in coupling strength, while errors of more than 3 dB
appear in MSTRIP. For $S/H_1 > 2$, MSTRIP rapidly loses accuracy, never pre-
dicting coupling weaker than -50 dB. MSTRIP2 remains within a few tenths of
one decibel of the stripline value.

It is noteworthy that, over the whole range of $S/H_1$ and $W/H_1$ tested, the
odd-mode impedances given by MSTRIP and MSTRIP2 are identical and exceed the
stripline values by 0.4 to 0.5 Ω. MSTRIP2 gives $Z_{oe}$ values which are simi-
larly 0.4 to 0.5 Ω higher than stripline values, while MSTRIP gives $Z_{oe}$
values about 1 Ω too high. Thus, even- and odd-mode impedance errors given
by MSTRIP2 track each other, giving accurate coupling values, while a roughly
0.5-Ω difference exists between the MSTRIP even- and odd-mode impedance
errors, resulting in large errors in coupling strength for weakly coupled
lines.

There is also a significant error in the even-mode effective dielectric
constant given by MSTRIP. This error is positive, opposite in sign to that
expected on the basis of the $Z_{oe}$ error. The error results in a predicted
even-mode phase velocity less than that of the odd mode. On this basis, a
forward coupling strength of -40 to -50 dB over a 90° line segment would be
predicted for all lines considered in Table I.
MSTRIP is adequate for design of couplers tighter than -25 dB, although it may give inaccurate values of directivity. For calculation of cross talk between closely spaced lines in applications such as MICs where space is at a premium, the current, more accurate version, MSTRIP2, is needed.

V. APPLICATION TO EXTREMELY LOW-IMPEDANCE LINES

In 1980 an MSTRIP user, J.C. Cozzie, pointed out a flaw which he had discovered when he attempted to determine microstrip parameters for extremely low-impedance lines: $Z_0 < 3 \Omega$, which requires strip widths of $W/H_1 > 70$ in the case $K = 2.45$ which was of interest to him. Cozzie located the flaw in the subroutine MGREEN, recognized it as a consequence of an approximation embedded in the integration procedure, and described how he eliminated it with changes including the substitution of a Gaussian quadrature procedure. (Cozzie was working with the 1971 or 1974 version of MSTRIP. By coincidence we had also converted MGREEN to Gaussian quadrature integration, calling IBM Scientific Subroutine DQG32, in the 1978 version.)

At Cozzie's instigation, we modified certain details of MGREEN to remove the flaw. At the time, we had the following further thoughts regarding very wide strips. First: if the scale of dimensions is such that the width becomes comparable to a half-wavelength (in a medium of dielectric constant $K_{eff}$ as evaluated by MSTRIP2) in the frequency range of interest, then spurious propagation effects and coupling problems are to be expected. In that case, it would probably be advisable to seek some alternative means to obtain the circuit function contemplated. Second: for widths of $W/H_1 > 20$ or so, very accurate results can be obtained by decomposing the strip capacitance into the sum of $W/H_1$ times a parallel-plate part per unit increment of $W/H_1$ plus an edge contribution. Once suitable limiting values of those two capacitance parameters have been determined by a few trials, the microstrip parameters for all cases of wider strips with the same substrate $K$ value can be quickly determined. Cozzie noted this suggestion and briefly presented his version of it in his paper.10
REFERENCES


APPENDIX

C******************************************************************************
C
C -MSTRIP2-
C
PARAMETERS OF MICROSTRIP TRANSMISSION LINES AND
OF COUPLED PAIRS OF MICROSTRIP LINES
C
IMPROVED -- VERSION OF AUG. 1, 1978
C
C REFERENCES -
C 3. J.A. WEISS AND T.G. BRYANT, ELECTRONICS LETTERS VOL. 6 P. 462 (JULY 23, 1970); SEE ALSO ERRATUM.
C
C FOR MICROSTRIP COMPRISING - A DIELECTRIC SUBSTRATE OF RELATIVE
C DIELECTRIC PERMITTIVITY $K$ AND THICKNESS $H_1$ LYING ON A CONDUCTING
C GROUND PLANE; A SINGLE STRIP OF WIDTH $W$ OR TWO PARALLEL STRIPS OF
C EQUAL WIDTH $W$ WITH INNER EDGES DISTANCE $S$ APART, LYING ON THE UPPER
C SURFACE OF THE SUBSTRATE; THICKNESS OF THE STRIP MATERIAL ASSUMED
C TO BE NOBLEIGIBLE; AN UPPER GROUND PLANE LOCATED PARALLEL TO AND
C DISTANCE $H_2$ ABOVE THE LOWER GROUND PLANE (OPTIONAL).
C
C THE PROGRAM COMPUTES THE FOLLOWING TRANSMISSION-LINE PARAMETERS
C FOR A SINGLE STRIP OR FOR BOTH THE EVEN AND ODD MODES OF A COUPLED
C PAIR OF STRIPS -
C
C CHARACTERISTIC IMPEDANCE;
C PHASE VELOCITY;
C EFFECTIVE DIELECTRIC CONSTANT $K_{eff}$;
C CAPACITANCE PER UNIT LENGTH PER STRIP (OPTIONAL).
C
C THE CALCULATION EMBODIES THE QUASI-STATIC APPROXIMATION, AS
C EXPLAINED IN REFERENCE 1; THE APPROXIMATION IS ACCURATE PROVIDED
C $H_1$ IS NO GREATER THAN A FEW PERCENT OF THE WAVELENGTH IN AN UN-
C BOUNDED MEDIUM OF PERMITTIVITY $K$.
C
C THE PROGRAM ACCEPTS ANY VALUE OF $K$, $S/H_1$, AND $W/H_1$.
C
C INPUT AND OUTPUT MEDIA ARE IDENTIFIED IN THE PROGRAM BY THE
C FOLLOWING NAMES - INPUT (USUALLY A CARD READER), IV; OUTPUT (USU-
C ALLY A LINE PRINTER), IW.

C
C INPUT DATA - THE INPUT DATA CARD IS WRITTEN IN NAMELIST FORMAT
C AND CONTAINS SIX DECIMAL NUMBERS AND ONE INTEGER NUMBER, ALL
C SEPARATED BY COMMAS, AS IN THE FOLLOWING EXAMPLE.
C
C $CONST WHl=0.1, DELW=0.2, NT=20, N=0.0, DIEK=9.6, STHl=0.4, AIR=1.0, $END
C
C THIS CARD SPECIFIES THE VALUES OF PROGRAM VARIABLES HAVING THE FOL-
C LOWING NAMES -
C
C $WIII, $DELW, $NT, $DIEK, $SIII, $ARC
C
C WHl IS THE STARTING VALUE OF W/Hi; DELW IS THE INCREMENT
C OF W/Hi; NT IS THE NUMBER OF LINES IN THE OUTPUT TABLE (EQUAL TO THE NUMBER
C OF VALUES OF W/Hi); R IS THE GROUND PLANE RATIO H2/HI (FOR THE
C OPTION OF NO UPPER GROUND PLANES, SET R = 0.0); DIEK IS THE RELA-
C TIVE DIELECTRIC PERMITTIVITY K OF THE SUBSTRATE; STHl IS THE VALUE
C OF S/Hi; AIR TAKES ONE OF THE TWO VALUES 0.0 (SINGLE STRIP) OR
C 1.0 (COUPLED STRIPS). THUS IN THE EXAMPLE THE OUTPUT TABLE WILL RE-
C PER TO THE EVEN AND ODD MODES OF COUPLED STRIPS WITH SPACING $HI
C = 0.4 ON SUBSTRATE OF PERMITTIVITY K = 9.6, NO UPPER GROUND PLANES,
C AND WILL LIST 20 LINES, FROM W/Hl = 0.1 THROUGH W/Hl = 2.0 IN
C STEPS OF 0.2.
C
C OUTPUT - THE OUTPUT FORMAT IS ILLUSTRATED IN THE FOLLOWING
C TABLE SHOWING THE FIRST LINE OF OUTPUT DATA FOR THE ABOVE EXAMPLE.
C
C H2/Hi = 0.0 K = 9.60 COUPLED STRIPS S/Hi = 0.4
C
C W/Hi 20(E) 20(O) V(E) V(O) K-HELP(E) K-HELP(O)
C ORMS
C 0.100 141.210 77.250 1.214 1.299 6.102 5.328
C
C SUBROUTINES REQUIRED - THE PROGRAM CALLS THREE SUBROUTINES OB-
C TAINED FROM THE IBM SCIENTIFIC SUBROUTINE PACKAGE (SSP). THEY ARE
C DGELS, SICI, AND DOG32. FOR DESCRIPTIONS AND LISTS OF THESE PROGRAMS
C SEE THE IBM SSP MANUAL. IN ADDITION, THE PROGRAM INCLUDES FIVE SUB-
C ROUTINES OF ITS OWN - OUTPUT, XGEM, AMAT, MPHl, AND MREEN AND ONE
C FUNCTION SUBPROGRAM - GINT. NOTES ON THE IMPROVEMENT DATED AUG. 1, 1976:
C THE INTEGRATION SUBROUTINE DOG32 (32-POINT GAUSSIAN QUAD-
C RATURE METHOD) REPLACES THE SUBROUTINE DOSF (SIMPSON’S RULE),
C RESULTING IN ACCURACY SUBSTANTIALLY BETTER THAN ONE PERCENT IN ALL
C CASES TESTED. REVISIONS AND TESTS PERFORMED BY R. C. LEWIS.
C
C NOTES ON DIMENSION REQUIREMENTS - FOR THE DETERMINATION OF
C CHARGE DISTRIBUTION EACH STRIP IS DIVIDED INTO M SUBSTRIPS. IN
C THE PRESENT PROGRAM M = 20, BUT THE PARAMETER M CAN BE INCREASED
C
C MST00500
C MST00510
C MST00520
C MST00530
C MST00540
C MST00550
C MST00560
C MST00570
C MST00580
C MST00590
C MST00600
C MST00610
C MST00620
C MST00630
C MST00640
C MST00650
C MST00660
C MST00670
C MST00680
C MST00690
C MST00700
C MST00710
C MST00720
C MST00730
C MST00740
C MST00750
C MST00760
C MST00770
C MST00780
C MST00790
C MST00800
C MST00810
C MST00820
C MST00830
C MST00840
C MST00850
C MST00860
C MST00870
C MST00880
C MST00890
C MST00900
C MST00910
C MST00920
C MST00930
C MST00940
C MST00950
C MST00960
C MST00970
C MST00980
C MST00990
FOR IMPROVED ACCURACY OR REDUCED FOR IMPROVED SPEED OF EXECUTION, THE DIMENSIONS OF THE VARIABLES DEPEND ON THE VALUE OF M AS FOLLOWS:

\[ V(M), A(U(M-1), X(3M-1), \Phi(3M-1), A(M(M+1)/2), B(M(M+1)/2) \]

**IMPLICIT REAL*8(A-H,O-Z)**

**DIMENSION V(20), AUX(19), GO(2)**

**COMMON/DIM/X(59), PHI(59), A(210), B(210)**

**NAMLIST/CONS/YWH, DELM, NT, R, DIERK, SHL, AIR**

**DATA GO,'Y','Y'/**

**CALL TIMES(DATE, TIME)**

**IV=5, IN=1, M=20, N=1**

**WRITE(IW,104)**

**DO 901 NRBP=1,25**

**EPS=1.63E-07**

**IF(NRBP .EQ. 1) GO TO 91**

**WRITE(6,102)**

**READ(IV,103) GOYN**

**IF(GOYN .EQ. GO(1)) GO TO 91**

**IF(GOYN .NE. GO(1) .AND. GOYN .NE. GO(2)) GO TO 92**

**GO TO 999**

**WRITE(6,101)**

**READ(IV,CONST)**

**IF(AIR) 38,7,8**

**WRITE(IW,105) R, DIERK**

**WRITE(IW,106)**

**GO TO 802**

**WRITE(IW,107) R, DIERK, SHL**

**WRITE(IW,108)**

**DO 902 K=1,MT**

**AK=W**

**WH=WH1+(AK-1.0)*DELM**

**CALL XGEN(M,WH,SHL)**

**NH=AIR+1**

**ADIERK=DIERK**

**DO 903 JJ=1,2**

**IF(JJ.EQ.1) DIERK=1.0**

**IF(JJ.EQ.2) DIERK=ADIERK**

**IF(R.EQ.0.0 .AND. DIERK.EQ.1.0) GO TO 39**

**CALL MRREM(M,WH,SHL,DIERK,R)**

**GO TO 804**

**CALL MPHJ(WH,M,AIR)**

**DO 904 JJ=1,NW**

**CALL APMAT(AIR,M)**

**DO 23 I=1,N**
F23

V(I)=1.0

IF(JJ .EQ. 1) CALL DGELS(V,A,M,N,EPS,IER,AUX)

IF(JJ .EQ. 2) CALL DGELS(V,B,M,N,EPS,IER,AUX)

IF(IER.NE.0) WRITE(IW,111) IER,EPS

111 FORMAT(' IER=',I3,':' IN SUBROUTINE DOHLS, SO THE CHARGE DENSITY

2 COULD NOT BE CALCULATED TO THE PRECISION OF ',E13.6,' DIGITS')

CAPSUM=0.0

DO 21 I=1,M

21 CAPSUM=CAPSUM+V(I)

CC=CAPSUM*111.256

IF(JJ .EQ. 1.AND. JJ .EQ. 1) CAP1E=CC

IF(JJ .EQ. 1.AND. JJ .EQ. 2) CAPKE=CC

IF(JJ .EQ. 2.AND. JJ .EQ. 1) CAP1O=CC

IF(JJ .EQ. 2.AND. JJ .EQ. 2) CAPKO=CC

903 CONTINUE

CALL OUTPUT(CAP1E,CAPKE,CAP1O,CAPKO,WH,IW,NU)

902 CONTINUE

WRITE(IW,110) DATE,TIME

101 FORMAT(/,3X,'CONST WH1,DELN,MT,R,DIEH,SH1,AIR ?',//)

102 FORMAT(/,3X,'CONTINUE? ('YES' OR 'NO')',//)

103 FORMAT(//)

104 FORMAT('1',//,5X,'J.A. WEISS',',',

2 'ADVANCES IN MICROWAVES, VOL. 8',//,7X,'PP. 295-320',',

3 'ACADEMIC PRESS, 1974',',',//,10X,'PARAMETERS OF MICROSTRIP',

4 'TRANSMISSION LINES',//,12X,'AND OF COUPLED PAIRS OF',

5 'MICROSTRIP LINES')

105 FORMAT(/,11X,'H2/H1 = ',F6.3,5X,'K = ',F6.3,4X,'SINGLE STRIP')

106 FORMAT(/,10X,'W/H1',/12X,'Z0',/14X,'V',/12X,'K-EFF',/11X,'C',//)

2 'OHMS',15X,'PF/X',12X,'OHMS',/10X,'PF/X',/)

107 FORMAT(/,3X,'H2/H1 = ',F6.3,4X,'K = ',F6.3,4X,'COUPLED STRIPS',

2 'S/H1 = ',F5.2)

108 FORMAT(/,3X,'W/H1',/6X,'Z0(B)',/4X,'Z0(O)',/6X,'V(B)',/4X,'V(O)',/4X,

2 'K-EFF(B) K-EFF(O)',/4X,'C(B)',/5X,'C(O)',/18X,'OHMS',/12X,

3 'OHMS',/10X,'PF/X',/12X,'OHMS',/)

109 FORMAT(/,3X,'AIR SHOULD BE 0.0 OR +1.0',//)

110 FORMAT(/,5X,2(A8,2X),//)

199 FORMAT(/)

901 CONTINUE

999 CONTINUE

CALL EXIT

STOP

END

SUBROUTINE OUTPUT(CAP1E,CAPKE,CAP1O,CAPKO,WH,IW,NU)

IMPLICIT REAL*8(A-H,O-Z)

DATA C/2.99792458/
EFFKE=CAPKE/CAP1R
RKE=DSGRT(EFFKE)
ZOE=1.0-04/(C*CAP1R*RKE)
VELE=(1.0/RKE)*C
IF(NN .EQ. 1) WRITES(IW,101) WH,ZOE,VELE,EFFKE,CAPKE
IF(NN .EQ. 1) GO TO 3
EFFKO=CAPKO/CAP10
RKO=DSGRT(EFFKO)
ZOO=1.0-04/(C*CAP1O*RKO)
VELO=(1.0/RKO)*C
WRITES(IW,103) WH,ZOE,ZOO,VELO,EFFKO,EFFKO,CAPKE,CAPKO
101 FORMAT(5(5X,P10.3))
2 4X,P6.3,1X,P6.3)
3 RETURN
END

SUBROUTINE XGEN(M,WH,SH1)
IMPLICIT REAL*8(A-H,O-Z)
COMMON/DIM/X(59),PHI(59),A(210),B(210)
AM=M
WHM=WH/AM
801 DO 901 I=1,M
AI=I
901 X(I)=(AI-1.0)*WHM
IF(SH1 .EQ. 0.0) GO TO 1
MM=2*M-1
802 DO 902 I=1,MM
AI=I
902 X(I+M)=AI*WHM+SH1
1 RETURN
END

SUBROUTINE AMAT(S,M)
IMPLICIT REAL*8(A-H,O-Z)
COMMON/DIM/X(59),PHI(59),A(210),B(210)
803 DO 903 I=1,M
INDEXI=M+1-I
804 DO 904 J=1,INDEXI
WP1=0
805 DO 905 K=1,J
WP1=WP1+K
905 WP2=WP1+K
806 IF(1 .LE. 2) GO TO 10
INDEX2=INDEX2+1
906 IF(1 .LE. 2) GO TO 10
SUBROUTINE MPHI (WH,M,S)
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/DIM/X(59),PHI(59),A(210),B(210)
AM=M
INDEX1=3*M-1
IF(S.EQ.0.0) INDEX1=M
EXWON=WH/(2.0*AM)
WYPON=1.0D 00
807 DO 907 K=1,INDEX1
XO=X(K)
EXP=XO+EXWON
EXN=XO-EXWON
WYP=2.0*WYPON
PHI(K)=(EXH/(2.0*EXWON))*DLOG( (EXN**2)/(EXH**2+WYP**2) )-(EXP
2.0*EXWON)**DLOG( (EXP**2)/(EXP**2*WYP**2))+(WYP/EXWON)
3.0*(DATAM(EXP/WYP)-DATAM(EXH/WYP))
907 CONTINUE
RETURN
END
SUBROUTINE MPBEM(M,WH,SH1,DIEK,R)
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/DIM/X(59),PHI(59),A(210),B(210)
COMMON /PASS/ R1,CO,BO,DIEK1
EXTERNAL GINT
AM=M
R1=R
DIEK1=DIEK
CO=WH/AM*0.5
X1=5.0
INT=2
H=X1/DFloat(INT)
IF(SH1.EQ.0.0) MA=M
IF(SH1.NE.0.0) MA=3*M-1
808 DO 908 MA=1,MA
BO=X(MA)
YTOT=0.0D0
XO=0.0
XL=0.0
908 CONTINUE
C COMPUTE FIRST INTEGRAL

809 DO 909 I=1,INT,1
  XU=UX+H
  CALL DOG32(XL,XU,GINT,YRSUL)
  YTOT=YTOT+YRSUL
  XL=XL+H
909 CONTINUE
  AI1=YTOT
C COMPUTE SECOND INTEGRAL

  S1=(CO+BO)*X1
  S2=(BO-CO)*X1
  CALL SICI(S1,C1,S1)
  AI2A=DSIN(S1)/X1-(CO+BO)*CI
  CALL SICI(S1,C1,S2)
  AI2B=DSIN(S2)/X1-(BO-CO)*CI
  AI2=AI2A-AI2B
  PHI(RE)=4.0*(AI1+1.0/((1.0+DIENK)*CO+2.0)*AI2)
908 CONTINUE
  RETURN
END

FUNCTION GINT(U)
IMPLICIT REAL*8(A-H,O-Z)
C COMMON /PASS/ R,CO,BO,DIENK
  V=(R-1.0)*U
  W1=CO*U
  W2=DCOSH(U)
  W3=DSINH(U)
  W4=DCOS(BO*U)
  IF(R .LE. 0)W4=W4*DSINH(V)
  IF(R .EQ. 0)DEN=W3-DIENK*W2
  IF(R .LE. 0)DEN=W3*DCOSH(V)+DIENK*W2*DSINH(V)
  GINT=DSIN(W1)/W2*W3/U*W4/DEN
  RETURN
END

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MSTRIP has undergone a succession of improvements since its original publication in 1969. Performance of the 1974 and later versions relating to aspects including weakly coupled (< 30 dB) microstrips, low shield heights (closer than substrate thickness), and extremely low- impedance lines will be discussed. A FORTRAN list of the 1978 version is appended.