```
      INTEGER TYPE
      COMPLEX Z(50)
      DIMENSION F(50), SWR(50)
1     READ (5, 2) N, UL, FC, TYPE
2     FORMAT (I5, 2F10.1, I5)
      CALL ONEPRT (F, Z, SWR, N, UL, FC, TYPE, 5, 6,  .TRUE. )
      GO TO 1
      END
```

```
    2    -0.1     6.55678       2
    6
17.17     16.97     15.19     14.99     13.20     13.00
 2.95      3.05      3.0
    6
15.97     15.37     14.14     13.52     12.30     11.69
 2.22      2.22      2.22
    1    -8.312      0.      5
    8
15.25     14.705    11.94     11.42      8.625     8.105     5.305     4.8
10.
12.       .0045     .1
```

TRANSMISSION-LINE ONE-PORT PARAMETERS FROM EXPERIMENTAL RESULTS

N = 2 UL =-0.100000E 00 CM FC = 6.55677986 GHZ TYPE = 2

FREQ GHZ	LAMBDAG CM	VSWR	RHO	RETURN LOSS DB	TRANSM LOSS DB	RES NLZD	REAC NLZD	CON NLZD	SUSC NLZD
10.0008	3.9700	3.0000	0.5000	6.0206	1.2494	1.1263	1.2139	0.4089	-0.4425
10.4660	3.6750	2.2200	0.3789	8.4299	0.6730	1.7703	0.7704	0.4749	-0.2067

TRANSMISSION-LINE ONE-PORT PARAMETERS FROM EXPERIMENTAL RESULTS

N = 1 UL = -8.31200 CM FC = 0.0 GHZ TYPE = 5

FREQ GHZ	LAMBDAG CM	VSWR	RHO	RETURN LOSS DB	TRANSM LOSS DB	RES NLZD	REAC NLZD	CON NLZD	SUSC NLZD
4.5309	6.6167	14.0507	0.8671	1.2385	6.0536	0.0723	-0.1282	3.3400	5.9170

Fig. 2. Simple main program for calling subroutine ONEPRT, typical data and results for TYPE=2 and TYPE=5 [2].

total attenuation between the above reference plane and the load reference plane. See [2] for details on the meaning of these values and how to obtain them.

Evaluation and Presentation of Results

If PRINT=.TRUE. then the subroutine will print out results as indicated in Fig. 2. Whenever the VSWR is greater than or equal to 10^4, the load impedance is assumed to be purely imaginary, the reflection coefficient and return loss are taken as 1 and 0, respectively, and the standing wave ratio and transmission loss are set to 10^4 for convenience. Otherwise, the calculations are made in the conventional manner [2]. The output variables F, Z, and SWR may, of course, be used in further calculations which the user wishes to make.

The program has been tested on the IBM 360/65.

Acknowledgment

The author would like, in particular, to thank J. F. Wells of Mullard Research Laboratories, Redhill, Surrey, England, P. A. Macdonald and B. H. McDonald of the Electrical Engineering Department, University of Manitoba, Winnipeg, Canada, who contributed to the development of the program.

References

[1] A. B. Giordano, "Measurement of standing wave ratio," in *Handbook of Microwave Measurements*, 3rd ed., vol. 1, M. Sucher and J. Fox, Eds. New York: Wiley, 1963, ch. 2.

[2] J. W. Bandler, "Precision microwave measurement of the internal parasitics of tunnel-diodes," *IEEE Trans. Electron Devices*, vol. ED-15, pp. 275–282, May 1968.

Response Program for an Inhomogeneous Cascade of Rectangular Waveguides

PURPOSE This package calculates the input admittance versus frequency to an arbitrarily terminated inhomogeneous cascade of rectangular waveguides with or without junction discontinuity effects.

LANGUAGE FORTRAN IV.

AUTHORS J. W. Bandler, Department of Electrical Engineering, McMaster University, Hamilton, Ont., Canada, and P. A. Macdonald, Numerical Applications Group, Department of Electrical Engineering, University of Manitoba, Winnipeg, Man., Canada.

AVAILABILITY Listing included in this description.

DESCRIPTION This package of subprograms calculates the complex normalized input admittance versus frequency to an arbitrarily terminated homogeneous or inhomogeneous cascade of rectangular waveguides operating in the H_{10} mode. Discontinuity effects due to small *symmetrical* steps can be taken into account.

There is a LOGICAL FUNCTION subprogram (Fig. 1) which tests constraints: CUTOFF (M, A, B, FL, FU, PRINT, UNIT, BEWARE, RANGE, SMALLA, SMALLB).

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```
      LOGICAL FUNCTION CUTOFF(M, A, B, FL, FU, PRINT, UNIT, BEWARE,
     XRANGE, SMALLA, SMALLB)
      DIMENSION A(1), B(1), MODE(3)
      LOGICAL PRINT, BEWARE, RANGE, SMALLA, SMALLB
      INTEGER UNIT
      DATA CBY2/14.989625/, MODE/'TE01', 'TE20', 'TE30'/
      CUTOFF = .FALSE.
      RANGE = .TRUE.
      BEWARE = .FALSE.
      SMALLA = .TRUE.
      SMALLB = .TRUE.
      MP2 = M + 2
      DO 9 I = 1, MP2
      IM1 = I - 1
      IP1 = I + 1
      FC = CBY2 / A(I)
      FCB = CBY2 / B(I)
      IF (FU .LT. FCB) GO TO 2
      BEWARE = .TRUE.
      IF (PRINT) WRITE (UNIT, 1) MODE(1), IM1
1     FORMAT ('0'A4, ' MODE MAY PROPAGATE IN GUIDE'I3)
2     IF (FL .GT. FC) GO TO 4
      CUTOFF = .TRUE.
      RANGE = .FALSE.
      IF (PRINT) WRITE (UNIT, 3) IM1
3     FORMAT ('0TE10 MODE CUTOFF IN GUIDE'I3)
      GO TO 5
4     IF (FU .LT. FC + FC) GO TO 5
      BEWARE = .TRUE.
      IF (PRINT) WRITE (UNIT, 1) MODE(2), IM1
      IF (FU .LT. FC + FC + FC) GO TO 5
      RANGE = .FALSE.
      IF (PRINT) WRITE (UNIT, 1) MODE(3), IM1
5     IF ( .NOT. RANGE) BEWARE = .TRUE.
      IF (I .EQ. MP2) RETURN
      ALPHA = A(I) / A(IP1)
      IF (ALPHA .GT. .7 .AND. ALPHA .LT. 1. / .7) GO TO 7
      SMALLA = .FALSE.
      IF (PRINT) WRITE (UNIT, 6) I
6     FORMAT ('0A'' / A < .7 => SMALL STEP APPROXIMATION DETERIORATING A
     XT JUNCTION'I3)
7     BETA = B(I) / B(IP1)
      IF (BETA .GT. .5 .AND. BETA .LT. 2.) GO TO 9
      SMALLB = .FALSE.
      IF (PRINT) WRITE (UNIT, 8) I
8     FORMAT ('0B'' / B < .5 => SMALL STEP APPROXIMATION DETERIORATING A
     XT JUNCTION'I3)
9     CONTINUE
      END
```

Fig. 1. FORTRAN IV listing of LOGICAL FUNCTION CUTOFF.

Input Variables

- M — an integer specifying the number of waveguide sections
- A — array of guide widths in cm from source to load including source and load guides
- B — array of guide heights in cm from source to load including source and load guides
- FL — the lower edge of the frequency band in GHz
- FU — the upper edge of the frequency band in GHz
- PRINT — a logical variable; when .TRUE. details of constraint violations are printed out; when .FALSE. nothing is printed out. The following can be printed out: whether the TE10 mode is cutoff or which higher order mode (TE01, TE20 or TE30) may propagate and in which guide (counting from source to load with the source guide as 0); and whether the small step approximation is deteriorating and at which junction (counting from source to load) it occurs
- UNIT — an integer specifying the data set reference number of the output unit.

Output Variables

- BEWARE — a logical variable; becomes .TRUE. if a higher-order mode can propagate
- RANGE — a logical variable; becomes .FALSE. if the frequency band is not in the range defined by the cutoff frequencies of the H_{10} and H_{30} modes
- SMALLA — a logical variable; becomes .FALSE. if the ratio of the widths of any adjacent guides lies outside the range 0.7 to 1/0.7
- SMALLB — a logical variable; becomes .FALSE. if the ratio of the heights of any adjacent guides lies outside the range 0.5 to 2
- CUTOFF — becomes .TRUE. if the dominant mode in any guide is cutoff in the band.

The response package (Fig. 2) is called by calling COMPLEX FUNCTION subprogram: YRECT (M, A, B, L, F, YLN, EFFECT, R, FCBYF). The variables M, A, and B are the same as before. The rest are defined as follows.

Input Variables

- L — array of guide lengths in cm from source to load including source and load guides whose lengths are immaterial since they are not used
- F — operating frequency in GHz between FL and FU
- YLN — complex normalized load admittance at frequency F
- EFFECT — a logical variable; when set .TRUE. includes susceptances due to small symmetrical H- and E-plane steps; when .FALSE. ignores discontinuities.

Output Variables

- R — the transformer impedance ratio (matched load to matched source)
- FCBYF — array of ratios of cutoff to operating frequency from source to load

```
      COMPLEX FUNCTION YRECT(M, A, B, L, F, YLN, EFFECT, R, FCBYF)
      REAL L(1), LAMBDA
      DIMENSION A(1), B(1), FCBYF(1)
      COMPLEX YLN, YI, P
      LOGICAL EFFECT
      DATA CBY2, C, TWOBYC / 14.989625, 29.97925, .0667128 /, PI, PIBY2
     X / 3.141593, 1.570796 /
      COMMON / RECT / LAMBDA, SK, SKP1, YK, YKP1
      MP2 = M + 2
      LAMBDA = C / F
      SK = CBY2 / (F * A(MP2))
      FCBYF(MP2) = SK
      SK = SQRT(1. - SK * SK)
      YK = SK / B(MP2)
      R = 1. / YK
      YI = YK * YLN
      DO 2 I = 1, M
      K = MP2 - I
      SKP1 = SK
      YKP1 = YK
      SK = CBY2 / (F * A(K))
      FCBYF(K) = SK
      SK = SQRT(1. - SK * SK)
      YK = SK / B(K)
      IF (EFFECT) YI = YI + CMPLX(0., BT(A, B, K))
      THETA = PI * AMOD(TWOBYC * F * L(K) * SK, 1.)
      IF (ABS(THETA - PIBY2) .GT. 1.E - 5) GO TO 1
      YI = YK * YK / YI
      GO TO 2
1     P = CMPLX(0., TAN(THETA))
      YI = YK * (YI + YK * P) / (YK + YI * P)
2     CONTINUE
      YKP1 = YK
      SKP1 = SK
      SK = CBY2 / (F * A(1))
      FCBYF(1) = SK
      SK = SQRT(1. - SK * SK)
      YK = SK / B(1)
      R = R * YK
      IF (EFFECT) YI = YI + CMPLX(0., BT(A, B, 1))
      YRECT = YI / YK
      RETURN
      END

      FUNCTION BT(A, B, K)
      REAL LAMBDA, LAMK, LAMKP1
      DIMENSION A(1), B(1)
      COMMON / RECT / LAMBDA, SK, SKP1, YK, YKP1
      LAMK = LAMBDA / SK
      LAMKP1 = LAMBDA / SKP1
      AK = A(K)
      AKP1 = A(K + 1)
      BK = B(K)
      BKP1 = B(K + 1)
      IF (AK - AKP1) 1, 2, 3
1     BH = BNH(AKP1, AK, LAMKP1) * YKP1
      GO TO 4
2     BH = 0.
      GO TO 4
3     BH = BNH(AK, AKP1, LAMK) * YK
4     IF (BK - BKP1) 5, 6, 7
5     BE = BNE(BKP1, BK, LAMKP1) * YKP1
      GO TO 8
6     BE = 0.
      GO TO 8
7     BE = BNE(BK, BKP1, LAMK) * YK
8     BT = BE + BH
      RETURN
      END

      FUNCTION BNH(A, APRM, LAMG)
      REAL LAMBDA, LAMG, LNHB
      COMMON / RECT / LAMBDA
      BETA = 1. - APRM / A
      HBETA = .5 * BETA
      LNHB = ALOG(HBETA)
      Q = A / (1.5 * LAMBDA)
      Q = 1. - SQRT(1. - Q * Q)
      QPRM = APRM / (1.5 * LAMBDA)
      QPRM = 1. - SQRT(1. - QPRM * QPRM)
      BNH = - LAMG / (A + A) * BETA * BETA * (1. + BETA) * LNHB /
     X(HBETA - 1.) * (1. - 27. * (Q + QPRM) / (8. * (1. - 8. * LNHB)))
      RETURN
      END
```

Fig. 2. FORTRAN IV listings of the function subprograms which calculate the response. They are brought into action by calling COMPLEX FUNCTION YRECT. The theory and most of the notation follows a paper by Bandler[1] although these programs are not identical to ones he used.

```
      FUNCTION BNE(B, BPRM, LAMG)
      REAL LAMG
      DELTA = 1. - BPRM / B
      HDELTA = .5 * DELTA
      BBYLG = B / LAMG
      BNE = BBYLG * HDELTA * DELTA * (ALOG(HDELTA) / (HDELTA - .5) + 1.
     X + 17. / 16. * BBYLG * BBYLG)
      RETURN
      END
```

Fig. 2. (*Cont'd*).

YRECT complex normalized input admittance at the operating frequency.

Variables L, PRINT, UNIT, BEWARE, RANGE, SMALLA, SMALLB, CUTOFF, YLN, EFFECT and YRECT must be defined and variables A, B, L and FCBYF must be dimensioned in the calling program. The user should first call CUTOFF. Depending on the outcome indicated by the logical variables the user can decide whether to call YRECT to evaluate the frequency response between FL and FU. If CUTOFF is .TRUE. and/or RANGE is. FALSE., then YRECT should not be called.

The theory follows Bandler[1,2] and the program has been tested on the IBM 360/65.

ACKNOWLEDGMENT

The cooperation of the Institute for Computer Studies of the University of Manitoba is acknowledged.

[1] J. W. Bandler, "Computer optimization of inhomogeneous waveguide transformers," this issue pp. 563–571.

[2] However, there are some differences between this program and the one used for optimizing inhomogeneous transformers. For example, most variables in the optimization program are COMMON and the magnitude of the reflection coefficient is obtained instead of the input admittance. Other calculations not required are also omitted. The relevant responses in Bandler[1] have been checked using this program.

Computer Programs for Smith-Chart Solutions

PURPOSE These subroutines are used in performing Smith-chart analysis. They are also applicable to even-odd mode analysis.

LANGUAGE Time-sharing FORTRAN (similar to FORTRAN II).

AUTHOR Joseph W. Verzino, Radar Design Corporation, Syracuse, N. Y. 13211.

AVAILABILITY Listing included in this description. Also, program is available in 8 channel, punched paper tape from the author.

DESCRIPTION These subroutines are normally used along with a time-shared computer. They are presently being used with the Graphic Control Time-Shared System. They have also been used on the General Electric and Com-Share Time-Shared Systems. They have also been used in batch processing computers such as IBM 1620, GE 235, SDS 930. Typical examples of the use of these subroutines can be found in the 1968 July and September issues of *Microwaves Magazine*.

```
480C      SMITH CHART SUBROUTINES
482C
483C
484C      USED ON G.E. TIME SHARE AND GRAPHIC CONTROLS TIMF SHARE
485C
486C
492C      AUTHOR: JOE VERZINO,LDV ELECTRO SCIENCE IND.,INC.
493C
494C             300 SO. GEDDES ST.,SYRACUSE,N.Y.,13204
495C
496C             TEL.   (315) 475-2181
497C
498C      A DETAILFD PROGRAM DFFINITION CAN BE FOUND IN THE JULY AND
499C      SFPT ISSUES OF MICROWAVES MAGAZINE OF 1968.
500 SUBROUTINE MATOXY(VMAG,VANGD,XX,YY)
510 VANGR=VANGD*3.14159265/180.
520 XX=VMAG*COS(VANGR)
530 YY=VMAG*SIN(VANGR)
540 RFTURN
550 FND
600 SUBROUTINE XYTOMA(XX,YY,VMAG,VANGD)
610 VMAG=SQRT(XX**2+YY**2)
620 VANGR=AT2(YY,XX)
630 VANGD=VANGR*180./3.14159265
640 RETURN
650 FND
700 SUBROUTINE STOZ(ZO,GM,GAD,RR,XX)
701 IF(GM-1.)12,13,13
702 13 IF(GAD-0.)12,14,12
704 14 RR=1.E10
705 XX=RR
706 GO TO 4
710 12 CALL MATOXY(GM,GAD,GR,GI)
720 CALL XYTOMA(1.+GR,GI,ATOP,PHITD)
730 CALL XYTOMA(1.-GR,-GI,ABOT,PHIBD)
740 CALL MATOXY(ZO*ATOP/ABOT,PHITD-PHIBD,RR,XX)
741 IF(RR)3,4,4
742 3RR=-RR
750 4RETURN
760 END
800 SUBROUTINE ZTOS(ZO,RR,XX,GM,GAD)
810 CALL XYTOMA(RR-ZO,XX,BT,ALPHT)
820 CALL XYTOMA(RR+ZO,XX,BB,ALPHB)
830 GM=BT/BB
840 GAD=ALPHT-ALPHB
850 RFTURN
860 END
900 SUBROUTINE ROTATE(THET1,FLDEG,THET2)
910 THET2=THET1-2.*ELDEG
920 THET2=AMODB(THET2,360.)
930 IF(THET2)20 ,51,70
940 20 IF(THET2+180.)121,51,51
950 121 THET2=THET2+360.
960 GO TO 51
970 70 IF (THET2-180.)51,51,50
980 50 THET2=THET2-360.
990 51 RETURN
999 END
1000 SUBROUTINE STEP(ZOLD,GMOLD,GADOLD,ZNEW,GMNEW,GADNFW)
1010 CALL STOZ(ZOLD,GMOLD,GADOLD,RR,XX)
1020 CALL ZTOS(ZNEW,RR,XX,GMNEW,GADNEW)
1030 RETURN
1040 END
2001 FUNCTION AT2(Y,X)
2002 IF(X)40,70,68
2003 68 AT2=ATAN(Y/X)
2004 GO TO 91
2005 70IF(Y)71,72,82
2006 71 AT2=-1.57079633
2007 GO TO 91
2008 72AT2=0.
2009 GO TO 91
2010 82 AT2=1.57079633
2011 GO TO 91
2012 40 IF(Y)51,51,50
2013 50 AT2=3.1415926+ATAN(Y/X)
2014 GO TO 91
2015 51 AT2=-3.1415926+ATAN(Y/X)
2016 91 RETURN
2017 END
3000 SUBROUTINE EVNODD(R,X)
3010 DIMENSION R(2),X(2)
3020 R(1)=0.0
3030 R(2)=1.E11
3040 X(1)=0.0
3050 X(2)=1.E11
3060 RETURN
3070 END
3100 SUBROUTINF GAMTOS(RCM,RCAD,S1MAG,S1ANGD,S2MAG,S2ANGD)
3110 DIMENSION RCM(2),RCAD(2),GR(2),GI(2)
3120 DO 1 I=1,2
3130 1 CALL MATOXY(RCM(I),RCAD(I),GR(I),GI(I))
3140 S1R=.5*(GR(2)+GR(1))
```

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