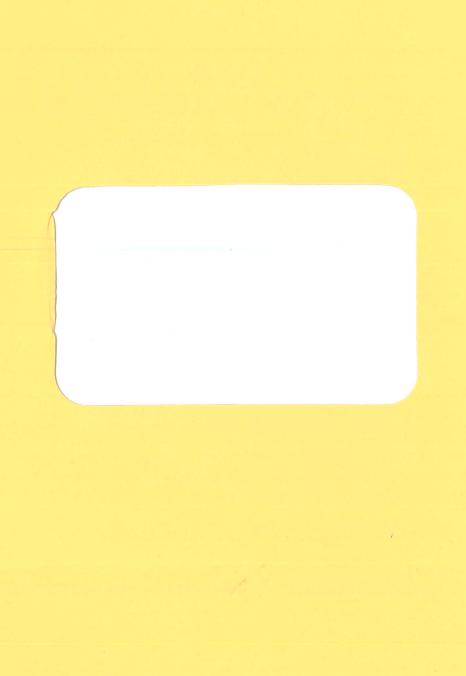


CONTIGUOUS BAND MULTIPLEXER SIMULATION AND OPTIMIZATION

OSA-84-MX-12-M July 16, 1984

Optimization Systems Associates

163 Watson's Lane, Dundas, Ontario, Canada



CONTIGUOUS BAND MULTIPLEXER SIMULATION AND OPTIMIZATION

OSA-84-MX-12-M July 16, 1984

Optimization Systems Associates 1984

No part of this document, computer program, source code, compiled code, related documentation and user manuals, magnetic tape, constituent subprograms, test programs, data and data files may be acquired, copied, reproduced, duplicated, executed, lent, disclosed, circulated, translated, transcribed or entered in any form into any machine without written permission from Optimization Systems Associates. Neither Optimization Systems Associates nor any other person, company, agency or institution make any warranty, express or implied, or assume any legal responsibility for the accuracy, completeness or usefulness of the material presented herein, or represent that its use would not infringe upon privately owned rights. This title page and original cover may not be separated from the contents of this document. COM DEV Ltd. of Cambridge, Ontario, Canada, is hereby granted permission to use this material, in whole or in part, for the simulation and design of microwave multiplexers. It is understood that full acknowledgement of source will accompany any disclosure or publication of the results of use of this material by any person or party.

INDEX

Section			
INTRODU	CTION		13
Ref	erences		
Fig	ures	1 Multiplexer configuration	
	:	2 Functional block of the package	
STRUCTU	RE OF T	HE PACKAGE	17
Int	oduction	ı	
Bas	ic Entrie	es	
Lov	er Leve	l Subroutines	
Fig	ure	1 Structure of MXSOS2	
THE MAIN	SEGMI	ENT MXSOS2	20
Ger	ieral Des	scription	
Mo	Modes of Operation of the Package		
Lis	of Varia	ables for all Modes of Operation	
Ref	erences		
MALL TO LOCAL	wpp cr	MANA ATTION, DODMAN DESCRIPTION	
MULTIPLI	EXER SI	MULATION: FORMAL DESCRIPTION	23
Ger	ieral Des	scription	
Lis	of Varia	ables for Multiplexer Simulation	
Sin	ulation	Entry (Subroutine SIMUL)	

MULT	IPLEXER S	SIMULATION: EXAMPLE	25	
	Introduction			
	Algorithm for Three-Channel, 12 GHz Multiplexer Simulation			
	Figures	1 Main program implementing the algorithm		
		2 Results of simulation		
MULT	IPLEXER S	SENSITIVITY ANALYSIS: FORMAL DESCRIPTION	37	
	General D	escription		
	List of Var	iables for Multiplexer Sensitivity Analysis		
	Sensitivity	Analysis Entry (Subroutine SIMGRD2)		
MULT	MULTIPLEXER SENSITIVITY ANALYSIS: EXAMPLE 4			
	Introduction			
	Algorithm for Three-Channel, 12 GHz Multiplexer Sensitivity Analysis			
	Figures	1 Main program for sensitivity analysis		
		2 Results of sensitivity analysis		
MULT	IPLEXER (OPTIMIZATION: FORMAL DESCRIPTION	51	
			-	
	General Description Formulation of the Problem			
	Basic Variables for Multiplexer Optimization			
	Arrays and Codes for Common Port Return Loss Optimization			
	Arrays and Codes for Insertion Loss Optimization			
	The Starting Point for Optimization			
	Optimization Entry (Subroutine MMLC1A)			
	References	3		

-4-

Table 1 Example of Functions, Specifications, Weighting Factors and Frequency Bands

Danas

Figure 1 Five channel example

MULTIPLEXER OPTIMIZATION: EXAMPLE

60

Introduction

Algorithm for Three-Channel, 12 GHz Multiplexer Optimization

Figures

- 1 Three channel specifications
- 2 Main program and FDF2 for optimization
- 3 Results of optimization
- 4 Plot of optimized result

SUBROUTINE FDF2

86

Purpose

List of Arguments

Common Blocks

Organization of the Subroutine

Figures

- 1 Assignment of variables for the first channel
- 2 Assignment of variables for remaining channels
- 3 Initiation of the loop to call SIMGRD2
- 4 Call to SIMGRD2 and processing of simultaneous return loss specifications
- 5 Assembly of minimax functions due to lower return loss specifications
- 6 Assembly of minimax functions due to upper return loss specifications
- 7 Processing of channel by channel simultaneous insertion loss specifications
- 8 Assembly of minimax functions due to lower insertion loss specifications only
- 9 Assembly of minimax functions due to upper insertion loss specifications only

SPECIAL FEATURES OF SUBROUTINE ARGUMENTS

105

Introduction Features Designed as Footnotes 107 SUBROUTINE FILTER Purpose Theory List of Arguments Related Software Comments References Figure 1 Listing SUBROUTINE FILABCD 111 Purpose Theory List of Arguments Related Software References Footnote 1 Inclusion of ideal transformers Figures 2 Admittance of terminated filter 3 Impedance inversion 4 Filter-junction combination

5 Listing

SUBI	ROUTINE MATMUL	117
	Purpose	
	List of Arguments	
	Related Software	
	Comments	
	Figure 1 Listing	
SUBI	ROUTINE BETAVAL	119
	Purpose	
	Theory	
	List of Arguments	
	Related Software	
	Figure 1 Listing	
SUBI	ROUTINE WGUIDE	122
	Purpose	
	Theory	
	List of Arguments	
	Related Software	
	Comment	
	Footnote	
	Figure 1 Listing	
SUBI	ROUTINE SEQUENC	125
	Purpose	
	Theory	
	List of Arguments	

Related Software

Comments References Footnote Figures 1 Filter-junction-spacing combination 2 Cascaded representation of the multiplexer 3 Products of adjacent chain matrices 4 Listing 130 SUBROUTINE RESPONS Purpose Theory List of Arguments Related Software References Footnote Figures 1 Simplified multiplexer structure for return loss 2 Simplified multiplexer structure for output voltage 3 Listing 135 SUBROUTINE INSOUT Purpose Theory List of Arguments Related Software References Footnote

Figure 1 Listing

SUBROUTINE PHASE

138

Purpose

Theory

List of Arguments

Related Software

Footnote

Figure 1 Listing

SUBROUTINE CSOLLU

140

Purpose

Theory

List of Arguments

Related Software

Figure 1 Listing

SUBROUTINE CONST1

142

Purpose

Theory

List of Arguments and COMMON Blocks

Related Software

Figure 1 Listing

SUBROUTINE DISPAT

144

Purpose

Theory

List of Arguments and COMMON Blocks Related Software Footnote Figure 1 Listing 147 SUBROUTINE DISPER Purpose Theory List of Arguments and COMMON Blocks Related Software Footnote Figure 1 Listing SUBROUTINE SIMUL 150 Purpose Theory List of Arguments and COMMON Blocks Related Software References Figure 1 Listing SUBROUTINE TOTAL2 156 Purpose List of Arguments Related Software Footnote Figure 1 Listing

SUBROUTINE DABCDF2

158

Purpose

Theory

List of Arguments and COMMON Blocks

Related Software

Reference

Footnote

Figure 1 Listing

SUBROUTINE DABCDG2

164

Purpose

Theory

List of Arguments

Related Software

Footnote

Figure 1 Listing

SUBROUTINE DRLOSS2

166

Purpose

Theory

List of Arguments

Related Software

Footnote

Figure 1 Listing

SUBROUTINE DVOLTA2			169
Pu	urpose		
Th	heory	Case 1	
		Case 2	
		Case 3	
Li	st of Arg	uments	
Re	Related Software		
Fo	ootnote		
Fi	gure	1 Listing	
SUBROU'	TINE IN	SERT	175
Pu	urpose		
Th	neory		
Li	st of Arg	uments	
Re	elated Sof	ftware	
Fo	ootnote		
Fi	gure	1 Listing	
		,	
SUBROU'	SUBROUTINE SIMGRD2 17		
Pu	urpose		
Th	heory		
Li	List of Arguments and COMMON Blocks		
Re	elated Soi	ftware	
Fi	igure	1 Listing	
INTERMEDIATE VARIABLES 183			

H1 to H14

H15 to H40

H41 to H212

HMX

INTRODUCTION

This report gives a user-oriented description of the MXSOS2 package consisting of twenty-two Fortran subroutines and a main segment. The package is designed for microwave multiplexer simulation, sensitivity analysis and optimization. The package and documentation have been prepared for the CDC 170/730 system with the NOS 2.1 -580/577 operating system and the Fortran Extended (FTN) version 4.8 compiler.

The design of a contiguous-band multiplexer structure (Fig. 1) is formulated as an optimization problem using a recently developed minimax algorithm of Hald and Madsen [1]. All design parameters of interest, e.g., filter spacings, input-output transformer ratios and filter coupling parameters, can be directly optimized.

A wide range of possible multiplexer optimization problems can be formulated and solved by appropriately defining specifications on common port return loss and individual channel insertion loss functions. The minimax error functions are created using those specifications, simulated exact multiplexer responses and weighting factors.

The minimax optimization package we use [2] requires functions and their first-order derivatives to be supplied. They are calculated using a theory developed for multiplexer structures, which employs some features of the method of forward and reverse analyses for cascaded structures developed by Bandler, Rizk and Abdel-Malek [3].

Fig. 2 shows the functional blocks of the package, which illustrates the three modes of operation of the package, namely, only multiplexer simulation, multiplexer sensitivity analysis (implies simulation) and multiplexer optimization (implies both simulation and sensitivity analysis).

If the multiplexer optimization option is selected three modes of optimization are allowed for, namely, only return loss optimization, only insertion loss optimization, simultaneous return loss and insertion loss optimization, all at user-defined sets of frequency

points. A suitable and sophisticated coding scheme has been developed (details of which are explained in the section MULTIPLEXER OPTIMIZATION: FORMAL DESCRIPTION), which creates a consecutively numbered set of minimax functions depending on whether we have only lower (upper) specifications, both or no specifications on a function of interest at a certain frequency point.

The coding scheme developed and employed in the package allows also a very flexible choice of optimization variables. In general, all parameters are candidates for optimization variables, however, with very little effort, the user can declare selected combinations of parameters to be optimization variables.

The package can exploit three commonly used practical models of the multiplexer, depending on whether the junctions are ideal or non-ideal (junction susceptance is included), whether the filters are lossless or lossy (dissipation is included) and whether the filters are modelled as dispersive or non-dispersive. The waveguide manifold is always assumed dispersive.

The aim of this report is to familiarize the user with the package using a mixture of formal description and illustrative examples. We consider, for example, a three-channel, 12 GHz multiplexer without dummy channels to illustrate many features of the package.

References

- [1] J. Hald and K. Madsen, "Combined LP and quasi-Newton methods for minimax optimization", <u>Mathematical Programming</u>, vol. 20, 1981, pp. 49-62.
- [2] J.W. Bandler and W.M. Zuberek, "MMLC a Fortran package for linearly constrained minimax optimization", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-5, 1982.
- [3] J.W. Bandler, M.R.M. Rizk and H.L. Abdel-Malek, "New results in network simulation, sensitivity and tolerance analysis for cascaded structures", <u>IEEE Trans. Microwave Theory Tech.</u>, vol. MTT-26, 1978, pp. 963-972.

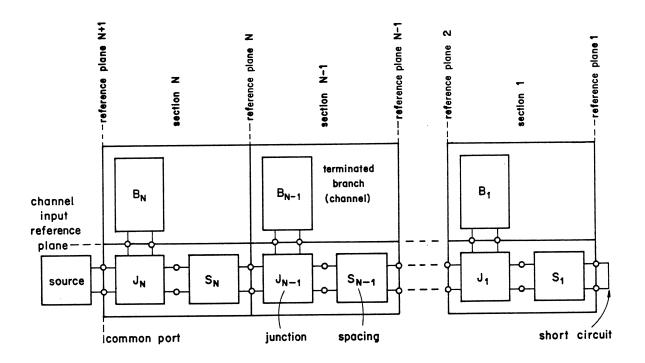


Fig. 1 The multiplexer configuration under consideration. $J_1, J_2, ..., J_N$ are arbitrarily defined 3-port junctions, $B_1, B_2 ..., B_N$ are terminated branches or channels which may each be represented in reduced cascade form and $S_1, S_2, ..., S_N$ are usually waveguide spacing elements.

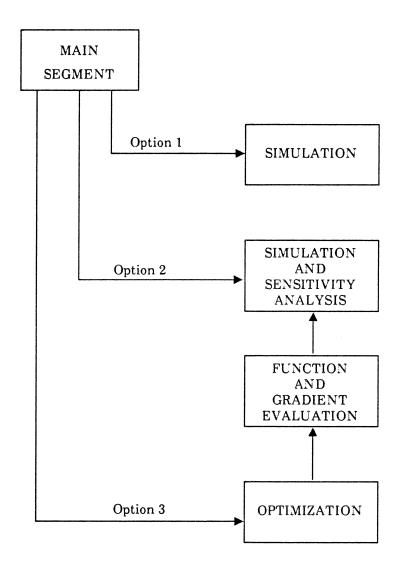


Fig. 2 Functional blocks of the computer package for multiplexer simulation, sensitivity analysis and optimization.

STRUCTURE OF THE PACKAGE

Introduction

The whole package has been modularized into 22 Fortran subroutines and one main segment. The overall structure of the package is shown in Fig. 1, where the calling and called subroutines are identified. The name of the main segment is MXSOS2 and is referred to by this name throughout the report.

Basic Entries

There are three basic entries to the package through the higher-level subroutines SIMUL, SIMGRD2 and MMLC1A, depending on the mode of operation of the package selected by the user in the main segment. If multiplexer simulation is required, the subroutine SIMUL is called. If multiplexer sensitivity analysis is required the subroutine SIMGRD2 is called. If multiplexer optimization is required the subroutine MMLC1A is called.

Lower Level Subroutines

The lower level subroutines form the heart of the simulation, which is conducted on an individual frequency point basis, and the required sensitivity analysis. The package is designed for an 8×8 coupling matrix, 16 channels and an arbitrary number of frequencies.

MMLC1A calls subroutine FDF2 in order to evaluate necessary error functions and partial derivatives. This is achieved at each frequency by a call to SIMGRD2, which in turn has at its disposal subroutines BETAVAL, FILTER, FILABCD, WGUIDE, SEQUENC, RESPONS, DABCDF2, DABCDG2, DRLOSS2, DVOLTA2 and INSERT, which are fully described in ensuing sections of this report. INSOUT and PHASE are called only by SIMUL.

Basic operations essential for simulation and sensitivity analysis are conducted by CSOLLU and MATMUL, the latter for matrix multiplications and the former for solving systems of complex linear equations using LU decomposition.

Other subroutines are DISPER, DISPAT, CONST1 and TOTAL2, also described fully later.

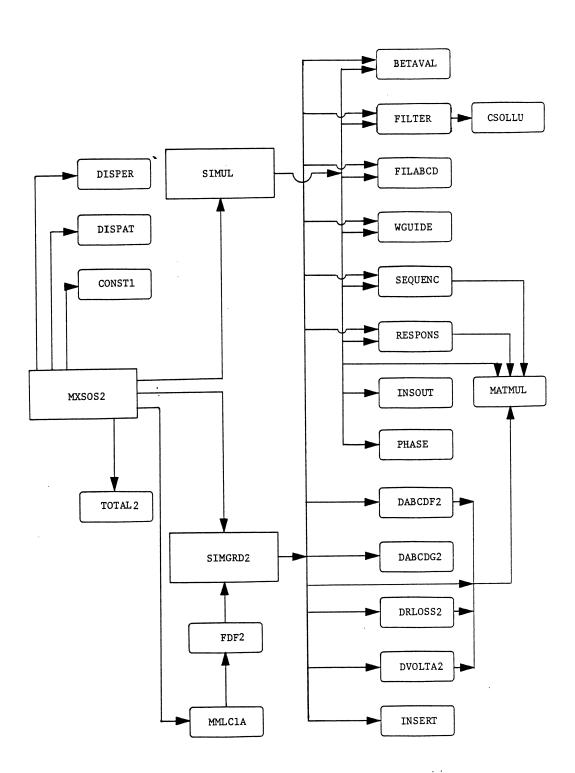


Fig. 1 The structure of the MXSOS2 package identifying the calling and called subprograms.

THE MAIN SEGMENT MXSOS2

General Description

MXSOS2 is a user defined main segment of the package for multiplexer simulation, sensitivity analysis and optimization. The program sets up arrays, initializes the data and executes some simple steps to organize the problem as required by the package. It consists of three parts. The first part initializes the data required for simulation; the second part initializes additional data required for sensitivity analysis; and the third part initializes the data required for the multiplexer optimization problem of interest, including specifications and weighting factors as well as the data required by the minimax optimization package MMLC [1]. Only common port return loss and channel insertion loss are handled for optimization. During simulation the group delay is estimated by differencing the phase at a pair of frequencies.

The user must provide appropriate dimensions for all arrays corresponding to the dimensions declared in all subroutines except for the MMLC package.

Modes of Operation of the Package

The MXSOS2 package can operate in three modes, namely, simulation, sensitivity analysis and optimization. To select the required function of the package the integer variable LMODE should be set to

- 1 if multiplexer simulation is required,
- 2 if multiplexer sensitivity analysis is required,
- 3 if multiplexer optimization is required.

List of Variables for all Modes of Operation

Part of the main segment is used to define the necessary data for any multiplexer problem. It must always be defined, regardless of the mode of operation of the package selected.

- 21 -

The following variables and arrays have to be defined:

NCH is an integer variable, which must be set to the number of filter channels including dummy channels (if any).

MO is an integer variable, which must be set to the order of the filters (the same for all filters, odd or even).

WO is a real array of dimension at least NCH. It must contain the center frequencies in MHz for all channels ordered consecutively.

QO is a real array of dimension at least NCH. It must contain the unloaded Q factor for the filters.

DIA is a real array of dimension at least NCH. It must contain the filter diameters in inches.

BW is a real array of dimension at least NCH. It must contain the channel bandwidths in MHz.

SPN1 is a real array of dimension at least NCH. It must contain the input transformer ratios (squared), one per channel.

SPN2 is a real array of dimension at least NCH. It must contain the output transformer ratios (squared), one per channel.

GL is a real array of dimension at least NCH. It must contain the values of channel terminating conductances, one per channel.

is a real array of dimensions at least NCH by MO by MO. It must contain the filter coupling parameters (channel, row, column), including nonzero diagonal elements to model asynchronous designs. Because of symmetry, only the upper part of the CM matrix has to be defined.

- 22 -

MAIN-3

CEL	is an integer array of dimensions at least NCH by MO by MO. It must contain
	the type of the coupling, 1 for a screw, -1 for an iris, corresponding to CM as
	above.

WGL is a real array of dimension at least NCH. It must contain the waveguide spacings for each channel, measured in inches along the manifold from the adjacent channel (distance from the short circuit for the first channel).

VS is a real variable, which must be set to the source voltage at the common port.

RS is a real variable, which must be set to the source resistance at the common port.

PI2 is a constant equal to twice π .

WIDTH is a real variable, which must be set to the manifold width in inches.

IFLAGJS is an integer variable, which must be set to 0 for ideal junctions, or to 1 for nonideal junctions.

IFLAGDP is an integer variable, which must be set to 0 if the filters are considered lossless or to 1 if the filters are considered lossy.

IDISPER is an integer variable, which must be set to 0 if the filters are nondispersive or to 1 if the filters are dispersive.

References

[1] J.W. Bandler and W.M. Zuberek, "MMLC - a Fortran package for linearly constrained minimax optimization", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-5, 1982.

MULTIPLEXER SIMULATION: FORMAL DESCRIPTION

General Description

A part of the main segment is used to generate frequencies at which simulation is to be performed. A frequency step of 1 MHz is assumed. None of the generated frequencies must be set exactly equal to any of the center frequencies. The subroutine SIMUL is called at each generated frequency. If a different frequency step is required, the frequency points for simulation have to be generated in an alternative way.

To perform the simulation, the subroutine SIMUL is called at each generated frequency. It returns the common port return loss function value, individual channel insertion loss function values and group delay.

Group delay is estimated from the phase difference at two frequencies, namely, the selected frequency and the selected frequency minus 0.5 MHz. Thus, a separate column of frequencies and group delays is generated and printed out. The evaluation of group delay is a true quadratic approximation at the selected frequency minus 0.25 MHz.

List of Variables for Multiplexer Simulation

The following variables have to be defined before the subroutine SIMUL is called:

FREQST is a real variable, which must be set to the starting frequency in MHz minus

1 MHz for simulation.

NFRSIM is an integer variable, which must be set to the number of frequency points at which simulation is performed.

Simulation Entry (Subroutine SIMUL)

The subroutine call is:

CALL SIMUL (FREQ, NCHAN, MORDER, ICOUNT, IFLAGJS, IFLAGDP, IDISPER, FRL, FIL, ANGLE).

The arguments are as follows:

FREQ is a real argument, which must be set to the actual frequency at which SIMUL is called.

NCHAN is an integer argument, which must be set to the number of filter channels including dummy channels (if any).

MORDER is an integer argument, which must be set to the order of the filters (the same for all filters).

ICOUNT is an integer argument, which is a counter for frequencies at which SIMUL is called.

IFLAGJS is an integer argument indicating ideal or nonideal junctions.

IFLAGDP is an integer argument indicating whether the filters are lossless or lossy.

IDISPER is an integer argument indicating whether the filters are dispersive or nondispersive.

FRL is a a real argument, which is set by the package to the value of the common port return loss in dB at the frequency FREQ.

FIL is a real array of length at least NCH. It is set by the package to the value of the insertion loss in dB for each channel at the frequency FREQ.

ANGLE is a real argument, which is set by the package to the phase at the frequency FREQ. It is used for estimating group delay.

MULTIPLEXER SIMULATION: EXAMPLE

Introduction

As an example of how to use the package in the simulation mode we present a threechannel, 12 GHz muliplexer simulation at 120 frequency points. The following algorithm defines all the steps required to run the program in the simulation mode of operation.

Algorithm for Three-Channel, 12 GHz Multiplexer Simulation

Step 1 Select the simulation mode of operation.

LMODE = 1.

Step 2 Define the number of channels.

NCH = 3.

Step 3 Define the order of the filters.

MO = 6.

Step 4 Define the center frequencies in MHz for all channels, namely, ω_{01} , ω_{02} , ω_{03} .

WO(1) = 12060.0,

WO(2) = 12020.0,

WO(3) = 11980.0.

Step 5 Define unloaded Q factors of the filters. In this example the unloaded Q factors are the same for all filters.

$$QO(I) = 12000.0, I = 1, 2, 3.$$

<u>Step 6</u> Define the circular waveguide diameter for the filters in inches. In this example the diameter is the same for all filters.

$$DIA(I) = 1.07, I = 1, 2, 3.$$

Step 7 Define the bandwidths $\Delta \omega$ of the channels in MHz. In this example the bandwidths are assumed to be the same for all channels.

$$BW(I) = 39.5$$
, $I = 1, 2, 3$.

Step 8 Define the input (output) transformer ratios n_1 (n_2) squared. In this example n_1 and n_2 are the same for all channels.

SPN1(I) = 0.69967,

$$I = 1, 2, 3.$$

SPN2(I) = 1.09450,

Step 9 Define the output conductances GL in ohms. Here, they are the same for all channels.

$$GL(I) = 1.0,$$
 $I = 1, 2, 3.$

Step 10 Define the symmetrical coupling matrix. Only the upper part of the coupling matrix has to be defined. In this example the non-zero coupling elements (same for all channels) are M_{12} , M_{23} , M_{34} , M_{36} , M_{45} , M_{56} .

CM (I, 1, 2) = 0.59395,
CM (I, 2, 3) = 0.53514,
CM (I, 3, 4) = 0.42471,
CM (I, 3, 6) =
$$-0.39967$$
,
CM (I, 4, 5) = 0.83371,

CM(I, 5, 6) = 0.76313,

where I = 1, 2, 3.

Step 11 Define the type of non-zero coupling elements in the filter (the same for all channels in this example). Integer 1 denotes a screw coupling and integer -1 denotes an iris coupling.

where I = 1, 2, 3.

Step 12 Define the section lengths (spacings along the waveguide manifold) in inches, namely, ℓ_1 , ℓ_2 and ℓ_3 .

WGL(1) = 0.641,

WGL(2) = 0.631,

WGL(3) = 0.633.

Step 13 Define the source voltage V_S in volts, the source resistance R_S in ohms and the manifold width w in inches.

VS = 1.0,

RS = 1.0,

WIDTH = 0.75.

Step 14 Define the flag for junction susceptance. In this example we set the flag to 1, which corresponds to nonideal junctions.

IFLAGJS = 1.

If the flag for junction susceptance is 1 the subroutine CONST1 is called. For details see section CONST1.

Step 15 Define the flag for filter dissipation. In this example the filters are assumed to be lossy.

IFLAGDP = 1.

If the flag for dissipation is 1 the subroutine DISPAT is called. For details see section DISPAT.

Step 16 Define the flag for dispersive effects in the coupled-cavity filters. In this example the filters are assumed to be dispersive.

IDISPER = 1.

If the flag for dispersion is 1 the subroutine DISPER is called. For details see section DISPER.

Step 17 Define the starting frequency in MHz minus 1 MHz and the number of frequency points at which simulation is to be performed.

FREQST = 11959.0,

NFRSIM = 120.

The listing of the main program implementing the steps given above and the results of simulation are shown on the following pages, in Figs. 1 and 2.

000001

PROGRAM MXSOS2(OUTPUT, TAPE6=OUTPUT)

WO

```
000002
THIS PROGRAM IS A USER DEFINED MAIN SEGMENT OF THE MXSOS2 PACKAGE
                                                                                            000003
FOR MULTIPLEXER SIMULATION, SENSITIVITY ANALYSIS AND OPTIMIZATION. THE PROCRAM SETS UP ARRAYS, INITIALIZES THE DATA AND EXECUTES SOME SIMPLE STEPS TO ORGANIZE THE PROBLEM AS REQUIRED BY THE PACKAGE.
                                                                                            000004
                                                                                           000005
                                                                                            000006
THE PARTS OF THREE PARTS. THE FIRST PART INITIALIZES THE DATA REQUIRED FOR SIMULATION, THE SECOND PART INITIALIZES ADDITIONAL DATA REQUIRED FOR SENSITIVITY ANALYSIS AND THE THIRD PART INITIALIZES THE DATA REQUIRED FOR THE MULTIPLEXER OPTIMIZATION PROBLEM
                                                                                            000007
                                                                                            000008
                                                                                            000009
                                                                                            000010
OF INTEREST INCLUDING SPECIFICATIONS AND WEIGHTING FACTORS AS WELL
                                                                                           000011
AS THE DATA REQUIRED BY THE MINIMAX OPTIMIZATION PACKAGE MMLC. AT THIS TIME ONLY COMMON PORT RETURN LOSS AND CHANNEL INSERTION LOSS IN DB ARE HANDLED FOR OPTIMIZATION. IN THE CASE OF SIMULATION
                                                                                            000012
                                                                                            000013
                                                                                            000014
GROUP DELAY IS ESTIMATED BY DIFFERENCING THE PHASE AT A PAIR
                                                                                            000015
OF FREQUENCIES.
                                                                                            000016
                                                                                            000017
THE USER MUST PROVIDE APPROPRIATE DIMENSIONS FOR THE FOLLOWING
                                                                                            000018
VARIABLES AFTER STUDYING THE COMMENTS PLACED THROUGHOUT THE MAIN SEGMENT MXSOS2. CORRESPONDING DIMENSIONS MUST BE DECLARED IN ALL
                                                                                           000019
                                                                                            000020
SUBROUTINES EXCEPT FOR THE MMLC PACKAGE.
                                                                                            000021
                                                                                            000022
REAL X(45), W(20000), B(1), C(1,1), T(3), DISP(16), Q0(16)
                                                                                            000023
REAL OMECA(47), SURL(47), SLRL(47), WURL(47), WLRL(47), SU(20,16), SL(20,16), WU(20,16), WL(20,16)
                                                                                            000024
                                                                                            000025
INTEGER RISCODE(47), SPCODE(20, 16), CHBCODE(16,2)
                                                                                            000026
REAL WO(16), BW(16), CM(16,8,8), PN1(16), PN2(16), SPN1(16), SPN2(16), CL(16), WCL(16), DIA(16)
                                                                                            000027
                                                                                           000028
                                                                                            000029
INTEGER CEL(16,8,8)
REAL FCNST(16), LAMRES(16), LAMDEL(16)
                                                                                           000030
REAL DRL(100), FIL(16), DIL(16,100)
                                                                                            000031
REAL ANGLE1(16), ANGLE2(16), CRDEL(16)
INTEGER IR(16), IRT(16), IPN1(16), IPN2(16), IWG(16)
                                                                                            000032
                                                                                           000033
                                                                                           000034
INTEGER LC(16,36), KC(16,36)
EXTERNAL FDF2
                                                                                           000035
COMMON /BLK1/WO, BW, PN1, PN2, GL, VS, RS, P12, WIDTH, NP1
                                                                                           000036
COMMON /BLK2/CM, WGL
                                                                                           000037
COMMON /BLK3/OMEGA, SURL, SLRL, WURL, WLRL, SU, SL, WU, WL,
                                                                                           000038
              RLSCODE, SPCODE, NCOUNT, MODE, NCH, MO, NFREQ, NFRL,
                                                                                           000039
         CHBCODE, IFLAGJS, IFLAGDP, IDISPER
                                                                                           000040
COMMON /BLK4/CBR, FCUT
                                                                                           000041
COMMON /BLK5/DISP
                                                                                           000042
COMMON/BLK6/FCNST, LAMRES, LAMDEL
                                                                                           000043
COMMON/BLK7/CEL
                                                                                           000044
COMMON/BLK8/IR, IRT, IPN1, IPN2, IWG, LC, KC
                                                                                           000045
DATA T/10HMULTIPLEXE, 10HR PROBLEM, 10HMXTST6C
                                                                                            000046
                                                                                           000047
THE MXSOS2 PACKAGE CAN OPERATE IN THREE MODES: SIMULATION, SENSITI
                                                                                           000048
VITY ANALYSIS AND OPTIMIZATION. TO SELECT THE REQUIRED FUNCTION OF
                                                                                           000049
THE PACKAGE SET LMODE TO
                                                                                           000050
1 - IF MULTIPLEXER SIMULATION IS REQUIRED,
                                                                                            000051
2 - IF MULTIPLEXER SENSITIVITY ANALYSIS IS REQUIRED,
                                                                                           000052
3 - IF MULTIPLEXER OPTIMIZATION IS REQUIRED.
                                                                                           000053
                                                                                           000054
                                                                                           000055
SELECT MODE OF OPERATION OF THE PACKAGE
                                                                                           000056
                                                                                           000057
LMODE= 1
                                                                                           000058
THIS PART OF THE MAIN SECMENT IS USED TO DEFINE THE DATA FOR
                                                                                           000059
MULTIPLEXER SIMULATION. IT MUST ALWAYS BE DEFINED, REGARDLESS OF THE MODE OF OPERATION OF THE PACKAGE SELECTED.
                                                                                           000060
                                                                                            000061
                                                                                           000062
         - NUMBER OF FILTER CHANNELS INCLUDING DUMMY CHANNELS
                                                                                           000063
NCII
         - ORDER OF FILTERS(THE SAME FOR ALL FILTERS, ODD OR EVEN)
MO
                                                                                           000064
           VECTOR OF CENTER FREQUENCIES IN MHZ, ONE PER CHANNEL
                                                                                           000065
```

Listing of MXSOS2 arranged for simulation only. Fig. 1

```
VECTOR OF UNLOADED Q FOR THE FILTERS, ONE PER CHANNEL
                                                                                               000066
       QO
                  VECTOR OF FILTER DIAMETERS IN INCHES, ONE PER CHANNEL VECTOR OF CHANNEL BANDWIDTHS IN MIZ, ONE PER CHANNEL VECTOR OF INPUT TRANSFORMER RATIOS(SQUARED), ONE PER
                                                                                               000067
C
       DIA
                                                                                               000068
C
       BW
       SPN1
                                                                                               000069
                                                                                               000070
C
                   CHANNEL
                   VECTOR OF OUTPUT TRANSFORMER RATIOS(SQUARED), ONE PER
                                                                                               000071
       SPN2
                                                                                               000072
C
                   CHANNEL
                   VECTOR OF CHANNEL TERMINATING CONDUCTANCES, ONE PER
Č
       GL
                                                                                               000073
                                                                                               000074
C
                   CHANNEL
                   SYMMETRICAL MATRIX OF COUPLING PARAMETERS (CHANNEL, ROW,
                                                                                               000075
\mathbf{C}
       CM
                              INCLUDING NONZERO DIAGONAL ELEMENTS TO MODEL
                                                                                               000076
\mathbf{C}
                   COLUMN),
                                                                                               000077
                   ASYNCHRONOUS DESIGNS
                                                                                               000078
                  SYMMETRICAL MATRIX FOR TYPE OF COUPLING, +1 FOR SCHEW,
C
       CEL
                    -1 FOR IRIS, CORRESPONDING TO CM AS ABOVE
                                                                                               000079
Ē
                   VECTOR OF WAVEGUIDE SPACINGS FOR EACH CHANNEL, MEASURED IN INCHES ALONG THE MANIFOLD FROM THE ADJACENT CHANNEL
Č
                                                                                               000080
       WGL
                                                                                               000081
C
C
                  (DISTANCE FROM THE SHORT CIRCUIT FOR THE FIRST CHANNEL)
SOURCE VOLTAGE AT THE COMMON PORT
SOURCE RESISTANCE AT THE COMMON PORT
                                                                                               000082
                                                                                               000083
\mathbf{c}
       VS
Č
                                                                                               0000334
       RS
                  CONSTANT EQUAL TO TWICE PI
MANIFOLD WIDTH IN INCHES
                                                                                               000085
       P12
       HTGIW
                                                                                               000086
C
                                                                                               000087
       DEFINE THE NUMBER OF CHANNELS AND THE ORDER OF THE FILTERS
                                                                                               000088
                                                                                               000089
       NCH=3
                                                                                               000090
                                                                                               000091
       MO=6
                                                                                               000092
       NP 1 = NCH+1
                                                                                               000093
                                                                                               000094
       DEFINE CENTER FREQUENCIES IN MHZ
\mathbf{C}
                                                                                               000095
\mathbf{C}
                                                                                               000096
       WO(1) = 12060.0
                                                                                               000097
       WO(2) = 12020.0
                                                                                               000098
        WO(3) = 11980.0
                                                                                               000099
       DEFINE UNLOADED Q FACTORS OF THE FILTERS
                                                                                               000100
                                                                                               000101
C
                                                                                               000102
       DO 5 I=1, NCH
        QO(1)=12000.0
                                                                                               000103
     5 CONTINUE
                                                                                               000104
                                                                                               000105
\mathbf{C}
                                                                                               000106
       DEFINE THE DIAMETER OF THE FILTERS IN INCHES
C
\mathbf{C}
                                                                                               000107
                                                                                               000108
       DO 70 I=1, NCH
                                                                                               000109
       DIA(I) = 1.07
                                                                                               000110
       CONTINUE
                                                                                               000111
        DEFINE BANDWIDTHS, INPUT/OUTPUT TRANSFORMER RATIOS AND OUTPUT
                                                                                               000112
                                                                                               000113
\mathbf{C}
       CONDUCTANCES
Č
                                                                                               000114
                                                                                               000115
       DO 1 I=1, NCH
       BW(1) = 39.5
                                                                                               000116
                                                                                               000117
        GL(I) = 1.0
                                                                                               000118
       SPN1(1)=0.69967
                                                                                               000119
       SPN2(I) = 1.09450
       PN1(I)=SQRT(SPN1(I))
                                                                                               000120
                                                                                               000121
        PN2(1) = SQRT(SPN2(1))
                                                                                               000122
     1 CONTINUE
                                                                                               000123
        DEFINE THE SYMMETRICAL COUPLING MATRIX. ONLY THE UPPER PART OF THE
CCC
                                                                                               000124
        CM MATRIX HAS TO BE DEFINED.
                                                                                               000125
                                                                                               000126
                                                                                               000127
       DO 30 I=1, NCH
                                                                                               000128
       DO 30 J=1, MO
DO 30 KK=1, MO
                                                                                               000129
       CM(I, J, KK) = 0.0
                                                                                               000130
```

Fig. 1 (continued) Listing of MXSOS2 arranged for simulation only.

```
30 CONTINUE
                                                                                              000131
        DO 2 I=1, NCH
                                                                                              000132
        CM(I,1,2) = 0.59395
                                                                                              000133
        CM(1,2,3) = 0.53514
                                                                                              000134
        CM(1,3,4) = 0.42471
                                                                                              000135
        CM(1,3,6) = -0.39967
                                                                                             000136
        CM(1,4,5) = 0.83371
                                                                                              000137
        CM(1,5,6) = 0.76313
                                                                                              000138
     2 CONTINUE
                                                                                              000139
                                                                                             000140
        DEFINE THE TYPE OF COUPLING IN THE FILTER
+1 >> SCREW GOUPLING -1 >> IR15
C
                                                                                             000141
                                              -1 >> IRIS COUPLING
\mathbf{c}
                                                                                             000142
\mathbf{C}
                                                                                             000143
        DO 71 I=1, NCH
                                                                                             000144
        DO 71 J=1, MO
                                                                                             000145
        DO 71 KK=1, MO
                                                                                             000146
        CEL(I,J,KK) = 0
                                                                                             000147
    71 CONTINUE
                                                                                             000148
\mathbf{C}
                                                                                             000149
        DO 72 1=1,NCH
                                                                                             000150
        CEL(I,1,2)=1
                                                                                             000151
        CEL(1,2,3) = -1
                                                                                             000152
        CEL(1,3,4)=1
                                                                                             000153
        CEL(1,3,6) = -1
                                                                                             000154
        CEL(1,4,5) = -1
                                                                                             000155
        CEL(1,5,6)=1
                                                                                             000156
\mathbf{C}
                                                                                             000157
        DO 72 J=1,MO
DO 72 KK=1,J
                                                                                             000158
                                                                                             000159
        CEL(I,J,KK) = CEL(I,KK,J)
                                                                                             000160
    72 CONTINUE
                                                                                             000161
\mathbf{C}
                                                                                             000162
        DEFINE THE SECTION LENGTHS (SPACINGS ALONG THE WAVEGUIDE MANIFOLD)
\mathbf{c}
                                                                                             000163
\mathbf{C}
                                                                                             000164
        WGL(1) = 0.641
                                                                                             000165
        WGL(2)=0.631
                                                                                             000166
        WGL(3) = 0.633
                                                                                             000167
\mathbf{C}
                                                                                             000168
\mathbf{C}
       DEFINE SOME CONSTANTS, SOURCE VOLTAGE, SOURCE RESISTANCE, TWICE PI
                                                                                             000169
\mathbf{c}
       MANIFOLD WIDTH
                                                                                             000170
\mathbf{C}
                                                                                             000171
       VS=1.0
                                                                                             000172
       RS=1.0
                                                                                             000173
       P12=8.0*ATAN(1.0)
                                                                                             000174
        WIDTH=0.75
                                                                                             000175
                                                                                             000176
       THE MXSOS2 PACKAGE CAN EXPLOIT THREE PRACTICAL MODELS OF THE
                                                                                             000177
C
       MULTIPLEXER AS DETERMINED BY THE PARAMETERS IFLAGJS, IFLAGDP
                                                                                             000178
CCCCCCC
       AND IDISPER.
                                                                                             000179
                                                                                             000180
        IFLAGJS
                                                                                             000181

    θ - IF JUNCTIONS ARE IDEAL
    1 - IF JUNCTIONS ARE NONIDEAL

                                                                                             000182
                                                                                             000183
                                                                                             000184
       IFLAGDP
                                                                                             000185
       0 - IF FILTERS ARE LOSSLESS
1 - IF FILTERS ARE LOSSY
000000
                                                                                             000186
                                                                                             000187
                                                                                             000188
       IDISPER
                                                                                             000189
       0 - IF FILTERS ARE DISPERSIVE
1 - IF FILTERS ARE NONDISPERSIVE
                                                                                             000190
                                                                                             000191
                                                                                             000192
C
       FLAC FOR JUNCTION SUSCEPTANCE (SET TO 0 OR 1)
                                                                                             000193
                                                                                             000194
       IFLAGJS= 1
                                                                                             000195
```

Fig. 1 (continued) Listing of MXSOS2 arranged for simulation only.

```
000196
         IF(IFLAGJS.NE.1)GO TO 42
                                                                                                        000197
\mathbf{C}
                                                                                                        000198
        CALL CONSTICWIDTH)
                                                                                                        000199
\mathbf{C}
    42 CONTINUE
                                                                                                        000200
                                                                                                        000201
        FLAG FOR FILTER DISSIPATION (SET TO 0 OR 1)
                                                                                                        000202
C
                                                                                                        000203
Ĉ
                                                                                                        000204
        IF(IFLAGDP.NE.1)GO TO 43
                                                                                                        000205
                                                                                                        000206
C
                                                                                                        000207
        CALL DISPAT(NCH, WO, BW, QO)
                                                                                                        000208
C
                                                                                                        000209
    43 CONTINUE
                                                                                                        000210
\mathbf{C}
        FLAG FOR DISPERSIVE EFFECTS IN THE COUPLED CAVITY FILTERS
                                                                                                        000211
C
                                                                                                        000212
         (SET TO 0 OR 1)
                                                                                                        000213
\mathbf{C}
                                                                                                        000214
         IDISPER= 1
                                                                                                        000215
         IF(IDISPER.NE.1)GO TO 44
                                                                                                        000216
C
                                                                                                        000217
        CALL DISPER(NCH, WO, BW, DIA)
                                                                                                        000218
\mathbf{C}
                                                                                                        000219
    44 CONTINUE
                                                                                                        000220
                                                                                                        000221
        CHECK WHETHER THE SIMULATION MODE IS REQUIRED
\mathbf{c}
                                                                                                        000222
\mathbf{C}
                                                                                                        000223
         IF(LMODE.NE.1)GO TO 16
                                                                                                        000224
        SIMULATION, CORRESPONDING TO LMODE=1
                                                                                                        000225
                                                                                                        000226
        THIS PART OF THE MAIN SEGMENT IS USED TO GENERATE FREQUENCIES AT WHICH SIMULATION IS TO BE PERFORMED. A FREQUENCY STEP OF 1 MHZ IS ASSUMED. NONE OF THE GENERATED FREQUENCIES MUST BE SET EQUAL TO
                                                                                                        000227
\bar{\mathbf{c}}
                                                                                                        000228
                                                                                                        000229
        ANY OF THE CENTER FREQUENCIES. SUBROUTINE "SIMUL" IS CALLED AT EACH CENERATED FREQUENCY. IF A DIFFERENT FREQUENCY STEP IS REQUIRED THE FREQUENCY POINTS FOR SIMULATION HAVE TO BE GENERATED IN A
                                                                                                        000230
                                                                                                        000231
                                                                                                        000232
                                                                                                        000233
         DIFFERENT WAY.
                                                                                                        000234
        FREQST - START FREQUENCY FOR SIMULATION
                                                                                                        000235
        FREQ - ACTUAL FREQUENCY AT WHICH "SIMUL" IS CALLED NFRSIM - NUMBER OF FREQUENCY POINTS FOR SIMULATION
                                                                                                        000236
                                                                                                        000237
                                                                                                        000238
                                                                                                        000239
         PRINT(6, 199)
                                                                                                        000240
   199 FORMAT(1H1)
                                                                                                        000241
         PRINT(6,205)
  205 FORMAT(6X. "FREQUENCY",5X. "RETURN LOSS",5X. "INSERTION LOSS",
1 8X, "FREQUENCY FOR",7X, "CROUP DELAY")
                                                                                                        000242
                                                                                                        000243
                                                                                                        000244
         PRINT(6,206)
   206 FORMAT(8X, "MHZ", 9X, "COMMON PORT", 9X, "DB", 17X, "CROUP DELAY", 9X, "NANO SECS")
                                                                                                        000245
                                                                                                        000246
                                                                                                        000247
C
                                                                                                        000248
\mathbf{C}
                                                                                                        000249
         THE FOLLOWING TWO PARAMETERS MUST BE DEFINED
\mathbf{c}
                                                                                                        000250
\mathbf{C}
                                                                                                        000251
         FREQST= 11959.0
                                                                                                        000252
         NFRS IM= 120
                                                                                                        000253
\mathbf{C}
                                                                                                        000254
         NCHAN=NCH
                                                                                                        000255
         MORDER= MO
                                                                                                        000256
         TREL= NCH+ 1
                                                                                                         000257
         DO 200 ICOUNT=1, NFRSIM
                                                                                                         000258
         FREQ=FREQST+FLOAT(ICOUNT)
                                                                                                         000259
         ITEST= INT(FREQ)
                                                                                                         000260
C
```

Fig. 1 (continued) Listing of MXSOS2 arranged for simulation only.

```
THE FOLLOWING STATEMENT PRINTS DASHED LINE EVERY 20 MHZ
                                                                                         000261
С
                                                                                         000262
  IF(MOD(ITEST, 20).EQ.0)PRINT(6,208)
208 FORMAT(90("-"))
                                                                                         000263
                                                                                         000264
       DO 210 I=1, NCH
                                                                                         000265
       IF(ABS(FREQ-WO(I)).LT.1.E-10)FREQ=FREQ+0.001
                                                                                         000266
  210 CONTINUE
                                                                                         000267
C
                                                                                         000268
       GROUP DELAY IS ESTIMATED FROM THE PHASE DIFFERENCE AT TWO
                                                                                         000269
CCCC
       FREQUENCIES, NAMELY, THE SELECTED FREQUENCY AND THE SELECTED FREQUENCY MINUS 0.5 MHZ. CONSEQUENTLY, THE EVALUATION IS A
                                                                                         000270
                                                                                         000271
       TRUE QUADRATIC APPROXIMATION AT THE SELECTED FREQUENCY MINUS 0.25 MHZ. THUS, A SEPARATE COLUMN OF FREQUENCIES AND GROUP
                                                                                         000272
                                                                                         000273
0000
       DELAYS IS GENERATED AND PRINTED OUT.
                                                                                         000274
                                                                                         000275
                                                                                         000276
       SUBTRACT 0.5 MHZ FROM FREQ
C
                                                                                         000277
       FREQ=FREQ-0.5
                                                                                         000278
C
                                                                                         000279
       CALL SIMUL(FREQ, NCHAN, MORDER, ICOUNT, IFLAGJS, IFLAGDP, IDISPER,
                                                                                         000280
                                                                                         000281
                   FRL, FIL, ANGLE 1)
C
                                                                                         000282
       RESET FREQ BY ADDING 0.5 MHZ
                                                                                         000283
\mathbf{c}
                                                                                         000284
       FREQ=FREQ+0.5
                                                                                         000285
C
                                                                                         000286
       CALL SIMUL(FREQ, NCHAN, MORDER, 1COUNT, 1FLAGJS, 1FLAGDP, IDISPER,
                                                                                         000287
                   FRL, FIL, ANGLE2)
                                                                                         000288
\mathbf{C}
                                                                                         000289
       DO 300 I=1,NCH
                                                                                         000290
       DELANG=ANGLE2(I)-ANGLE1(I)
                                                                                         000291
       PI=PI2/2.0
                                                                                         000292
       IF (DELANG. GT. PI) DELANG-DELANG-PI2
                                                                                         000293
       GRDEL(1) = -2000.0*DELANG/P12
                                                                                         000294
                                                                                         000295
  300 CONTINUE
                                                                                         000296
C
C
C
       THE FOLLOWING STATEMENT CAUSES THE PRINTING OF INSERTION LOSS
                                                                                         000297
       FUNCTION VALUES ONLY FOR THE BAND OF INTEREST.
                                                                                         000298
\mathbf{C}
                                                                                         000299
       IF(MOD(ITEST, 40).EQ. 0) IREL= IREL-1
                                                                                         000300
\mathbf{c}
                                                                                         000301
       GROUP DELAY IS ESTIMATED AT FREQ MINUS 0.25 MHZ
                                                                                         000302
\mathbf{c}
C
                                                                                         000303
       FRGROUP=FREQ-0.25
                                                                                         000304
       PRINT(6,207) FREQ, FRL, FIL(IREL), FRGROUP, GRDEL(IREL)
                                                                                         000305
  207 FORMAT(6X, F7.1, 9X, F5.2, 12X, F5.2, 17X, F8.2, 10X, F8.2)
                                                                                         000306
  200 CONTINUE
                                                                                         000307
   16
       CONTINUE
                                                                                         000308
       STOP
                                                                                         000309
                                                                                         000310
       END
```

Fig. 1 (continued) Listing of MXSOS2 arranged for simulation only.

FREQUENCY MHZ	RETURN LOSS COMMON PORT	INSERTION LOSS DB	FREQUENCY FOR GROUP DELAY	GROUP DELAY NANO SECS
11960.0	3.10	6.99	11959.75	102.10
11961.0	5.24	4.13	11960.75	101.31
11962.0	6.23	3.13	11961.75	77.10
11963.0	6.96	2.60	11962.75	61.44
11964.0	7.89	2.20	11963.75	53.6 3
11965.0	8.93	1.88	11964.75	49.01
11966.0	9.77	1.66	11965.75	45.41
11967.0	10.26	1.53	11966.75	42.17
11968.0	10.46	1.45	11967.75	39.31
11969.0	10.57	1.39	11968.75	36.95
11970.0	10.76	1.34	11969.75	35.15
11971.0	11.12	1.28	11970.75	33.86
11972.0	11.68	1.21	11971.75	32.99
11973.0	12.44	1.14	11972.75	32.42
11974.0	13.38	1.07	11973.75	32.03
11975.0	14.40	1.02	11974.75	31.73
11976.0	15.35	.97	11975.75	31.47
11977.0	16.03	.95	11976.75	31.20
11978.0	16.33	.93	11977.75	30.94
11979.0	16.31	.93	11978.75	30.69
11980.0	16.13	.94	11979.75	30.51
11981.0	16.00	.94	11980.75	30.43
11982.0	16.02	.95	11981.75	30.49
11983.0	16.30	.95	11982.75	30.69
11984.0	16.87	. 95	11983.75	31.05
11985.0	17.80	.94	11984.75	31.57
11986.0	19.14	.94	11985.75	32.24
11987.0	20.94	.94	11986.75	33.04
11988.0	23.15	. 95	11987.75	33.97
11989.0	25.34	.97	11988.75	35.94
11990.0	26.27	1.01	11989.75	36.28
11991.0	25.53	1.05	11990.75	37.75
11992.0	24.41	1.11	11991.75	39.56
11993.0	23.80	1.19	11992.75	41.86
11994.0	23.95	1.28	11993.75	44.88
11995.0	24.98	1.40	11994.75	48.92
11996.0	26.91	1.56	11995.75	54.52
11997.0	29.91	1.81	11996.75	62.74
11998.0	34.35	2.25	11997.75	75.78
11999.0	26.62	3.25	11998.75	97.49

Fig. 2 Results of the three-channel simulation problem.

12000.0	19.41	8.30	11999.75	99.97
12001.0	16.95	4.12	12000.75	121.27
12002.0	16.88	2.66	12001.75	94.29
12003.0	18.41	2.04	12002.75	74.44
12004.0	20.77	1.70	12003.75	62.68
12005.0	22.64	1.48	12004.75	54.99
12006.0	22.67	1.34	12005.75	49.51
12007.0	21.71	1.25	12006.75	45.39
12008.0	20.99	1.18	12007.75	42.26
12009.0	20.87	1.12	12008.75	39.85
12010.0	21.40	1.06	12009.75	37.99
12011.0	22.61	1.02	12010.75	36.54
12012.0	24.63	.97	12011.75	35.38
12013.0	27.80	.94	12012.75	34.44
12014.0	32.89	.91	12013.75	33.66
12015.0	39.10	.90	12014.75	33.01
12016.0	34.27	.88	12015.75	32.46
12017.0	30.06	.87	12016.75	32.02
12018.0	27.89	. 87	12017.75	31.69
12019.0	26.98	. 87	12018.75	31.47
12020.0	27.07	. 86	12019.75	31.37
12021.0	28, 19	. 86	12020.75	31.38
12022.0	30.72	. 86	12021.75	31.50
12023.0	36.23	.87	12022.75	31.72
12024.0	53.29	. 88	12023.75	32.04
12025.0	34.24	.89	12024.75	32.44
12026.0	28.52	.91	12025.75	32.93
12027.0	25.35	.94	12026.75	33.54
12028.0	23.46	.97	12027.75	34.30
12029.0	22.45	1.00	12028.75	35.25
12030.0	22.21	1.04	12029.75	36.47
12031.0	22.73	1.08	12030.75	38.04
12032.0	23.96	1.13	12031.75	40.03
12033.0	25.19	1.19	12032.75	42.53
12034.0	24.32	1.29	12033.75	45.65
12035.0	21.58	1.43	12034.75	49.62
12036.0	19.21	1.62	12035.75	54.95
12037.0	18.11	1.89	12036.75	62.92
12038.0	18.66	2.33	12037.75	76.25
12039.0	18.55	3.34	12038.75	98.98

Fig. 2 (continued) Results of the three-channel simulation problem.

12040.0	14.39	8.29	12039.75	100.78
12041.0	12.67	4.22	12040.75	119.40
12042.0	13.21	2.76	12041.75	92.79
12043.0	15.07	2.10	12042.75	74.10
12044.0	16.90	1.74	12043.75	62.76
12045.0	17.40	1.53	12044.75	54.94
12046.0	16.93	1.40	12045.75	49.20
12047.0	16.54	1.31	12046.75	44.97
12048.0	16.64	1.23	12047.75	41.87
12049.0	17.26	1.16	12048.75	39.61
12050.0	18.32	1.09	12049.75	37.91
12051.0	19.56	1.03	12050.75	36.57
12052.0	20.38	. 99	12051.75	35.4 3
12053.0	20.14	.97	12052.75	34.42
12054.0	19.03	. 96	12053.75	33.50
12055.0	17.73	. 96	12054.75	32.66
12056.0	16.65	. 96	12055.75	31.94
12057.0	15.89	.97	12056.75	31.37
12058.0	15.47	. 97	12057.75	30.97
12059.0	15.35	. 97	12058.75	30.75
12060.0	15.47	.96	12059.75	30.71
12061.0	15.74	. 96	12060.75	30.82
12062.0	15.99	. 95	12061.75	31.04
12063.0	15.99	.96	12062.75	31.33
12064.0	15.55	.98	12063.75	31.63
12065.0	14.72	1.01	12064.75	31.92
12066.0	13.69	1.07	12065.75	32.19
12067.0	12.69	1.13	12066.75	32.50
12068.0	11.84	1.20	12067.75	32.91
12069.0	11.21	1.28	12068.75	33.55
12070.0	10.80	1.34	12069.75	34.55
12071.0	10.59	1.40	12070.75	36.02
12072.0	10.49	1.45	12071.75	38.97
12073.0	10.34	1.53	12072.75	40.70
12074.0	9.90	1.66	12073.75	43.80
12075.0	9.06	1.87	12074.75	47.25
12076.0	8.00	2.18	12075.75	51.19
12077.0	7.02	2.60	12076.75	56.81
12078.0	6.26 5.30	3.12 4.10	12077.75 12078.75	67.45 88.14
12079.0			12M2H 25	2526 144

Fig. 2 (continued) Results of the three-channel simulation problem.

MULTIPLEXER SENSITIVITY ANALYSIS: FORMAL DESCRIPTION

General Description

The second part of the main segment is used to define codes for multiplexer parameters w.r.t. which we want to find the sensitivities. The user must define the number of coupling variables per channel, codes to identify variables for input-output transformer ratios, waveguide spacings and variables contained in the coupling matrices.

Subroutine SIMGRD2 is called at each frequency defined in the vector OMEGA (I). The parameter IR(I) = 0 signifies that no elements of the filter coupling matrices are optimization variables.

List of Variables for Multiplexer Sensitivity Analysis

The following variables have to be defined before the subroutine SIMGRD2 is called.

- IR is an integer array of dimension at least NCH. It must contain the number of coupling parameters being variables for each channel.
- LC is an integer array of dimensions at least NCH by MO(MO-1)/2 + MO. It must contain the row indices of coupling parameters being variables for each channel in the form LC (channel, row index).
- KC is an integer array of dimensions at least NCH by MO(MO-1)/2 + MO. It must contain the column indices of coupling parameters being variables for each channel in the form KC (channel, column index).
- IPN1 is an integer array of dimension at least NCH, indicating whether the input transformer ratio is an optimization variable (IPN1(I) = 1) or not (IPN1(I) = 0).
- IPN2 is an integer array of dimension at least NCH, indicating whether the output transformer ratio is an optimization variable (IPN2(I) = 1) or not (IPN2(I) = 0).

IWG is an integer array of dimension at least NCH indicating whether the waveguide section length is an optimization variable (IWG(I) = 1) or not (IWG(I) = 0).

OMEGA is a real array of dimension at least NFREQ (the number of frequency points at which the sensitivity analysis is to be performed). It must contain arbitrary frequencies (except center frequencies) at which the sensitivity analysis is to be performed.

FRSNS is a real variable, which must be set to the actual frequency at which the subroutine SIMGRD2 is called.

Sensitivity Analysis Entry (Subroutine SIMGRD2)

The subroutine call is:

CALL SIMGRD2 (FRSNS, FRL, DRL, FIL, DIL, NCHAN, MORDER, ICOUNT, IFLAGJS, IFLAGDP, IDISPER).

The arguments are as follows:

FRSNS is a real argument, which must be set to the actual frequency at which the subroutine SIMGRD2 is called.

FRL is a real argument, which on exit from SIMGRD2, is set by the package to the value of the common port return loss in dB at the frequency FRSNS.

DRL is a real array of dimension at least NV (the total number of variables w.r.t. which sensitivities are required). On exit from SIMGRD2, it is set by the package to the sensitivities of the common port return loss w.r.t. all variables.

FIL is a real array of length at least NCH. On exit from SIMGRD2, it is set by the package to the values of the insertion loss in dB for each channel at the frequency FRSNS.

DIL is a real array of dimensions at least NCH by NV (channel, variable). On exit from SIMGRD2, it is set by the package to the sensitivities of the insertion loss function for each channel w.r.t. all variables.

Arguments NCHAN, MORDER, ICOUNT, IFLAGJS, IFLAGDP, IDISPER have the same meaning as in the simulation entry described in the SIMULATION section.

MULTIPLEXER SENSITIVITY ANALYSIS: EXAMPLE

Introduction

To illustrate the use of the package in the sensitivity analysis mode of operation we present how to obtain the sensitivities of the three-channel multiplexer responses w.r.t. some multiplexer parameters. The following algorithm defines all the steps required to run the program in the sensitivity analysis mode of operation.

Algorithm for Three-Channel, 12 GHz Multiplexer Sensitivity Analysis

Step 1 Select the sensitivity analysis mode of operation.

LMODE = 2

- Step 2 Execute Steps 2-16 of the algorithm presented in the SIMULATION EXAMPLE section.
- Step 3 Define the number of coupling variables per channel. In this example we select
 12 couplings (the same for all filters) per channel as variables including cavity
 resonant frequencies.

$$IR(I) = 12, I = 1, 2, 3.$$

<u>Step 4</u> Define codes to identify variables for waveguide spacings. In this example we want to declare all waveguide spacings as variables

$$IWG(I) = 1,$$
 $I = 1, 2, 3.$

Step 5 Define codes to identify variables for input and output transformer ratios. In this example all input and output transformer ratios are declared as variables.

$$IPN1(I) = 1$$
,

$$IPN2(I) = 1.$$

where I = 1, 2, 3.

- Step 6 Evaluate the total number of variables accumulated after each section. To execute this step subroutine TOTAL2 is called. On exit from TOTAL2 one of the arguments, namely, IRT(I) contains the total number of variables accumulated after each section. For details see section TOTAL2.
- Step 7 Define codes to identify variables contained in the coupling matrices. For the three-channel multiplexer considered the same variables are selected for all channels, namely,

M ₁₁ :	row index	LC(I,1)=1,	column index	KC(I,1)=1
M ₁₂ :	row index	LC(I, 2) = 1,	column index	KC(I,2)=2
M ₂₂ :	row index	LC(I, 3) = 2,	column index	KC(I,3)=2
M ₂₃ :	row index	LC(I,4)=2	column index	KC(I,4)=3
M ₃₃ :	row index	LC(I, 5) = 3,	column index	KC(I, 5) = 3
M ₃₄ :	row index	LC(I, 6) = 3,	column index	KC(I, 6) = 4
M ₃₆ :	row index	LC(I, 7) = 3,	column index	KC(I, 7) = 6
M ₄₄ :	row index	LC(I, 8) = 4,	column index	KC(I,8)=4
M ₄₅ :	row index	LC(I, 9) = 4,	column index	KC(I, 9) = 5
M ₅₅ :	row index	LC(I, 10) = 5,	column index	KC (I, 10) = 5
M ₅₆ :	row index	LC(I, 11) = 5,	column index	KC(I, 11) = 6
M ₆₆ :	row index	LC(I, 12) = 6,	column index	KC(I, 12) = 6.

Step 8 Define the number of frequency points for sensitivity analysis.

NFREQ = 3.

Step 9 Define the frequency points at which the sensitivity analysis is to be performed.

OMEGA(1) = 12062.0

OMEGA(2) = 12022.0

OMEGA(3) = 11982.0

The listing of the main program implementing the steps given above and the results of the sensitivity analysis are shown on the following pages, in Figs. 1 and 2.

```
PROGRAM MXSOS2(OUTPUT, TAPE6=OUTPUT)
                                                                                                                  944441
                                                                                                                   000002
C
         THIS PROGRAM IS A USER DEFINED MAIN SEGMENT OF THE MXSOS2 PACKAGE
                                                                                                                   000003
         THIS PROGRAM IS A USER DEFINED MAIN SEGMENT OF THE MXSOSZ PACKAGE FOR MULTIPLEXER SIMULATION, SENSITIVITY ANALYSIS AND OPTIMIZATION. THE PROGRAM SETS UP ARRAYS, INITIALIZES THE DATA AND EXECUTES SOME SIMPLE STEPS TO ORGANIZE THE PROBLEM AS REQUIRED BY THE PACKAGE. IT CONSISTS OF THREE PARTS. THE FIRST PART INITIALIZES THE DATA REQUIRED FOR SIMULATION, THE SECOND PART INITIALIZES ADDITIONAL.
                                                                                                                  000004
000000
                                                                                                                  000005
                                                                                                                  000006
                                                                                                                   000007
                                                                                                                   800000
         DATA REQUIRED FOR SENSITIVITY ANALYSIS AND THE THIRD PART INITIA-
LIZES THE DATA REQUIRED FOR THE MULTIPLEXER OPTIMIZATION PROBLEM
                                                                                                                   000009
                                                                                                                  000010
         OF INTEREST INCLUDING SPECIFICATIONS AND WEIGHTING FACTORS AS WELL AS THE DATA REQUIRED BY THE MINIMAX OPTIMIZATION PACKAGE MMLC. AT
                                                                                                                  000011
                                                                                                                   000012
C
         THIS TIME ONLY COMMON PORT RETURN LOSS AND CHANNEL INSERTION LOSS IN DB ARE HANDLED FOR OPTIMIZATION. IN THE CASE OF SIMULATION GROUP DELAY IS ESTIMATED BY DIFFERENCING THE PHASE AT A PAIR
                                                                                                                   000013
                                                                                                                   000014
                                                                                                                   000015
                                                                                                                   000016
         OF FREQUENCIES.
                                                                                                                   000017
\mathbf{C}
                                                                                                                   000018
         THE USER MUST PROVIDE APPROPRIATE DIMENSIONS FOR THE FOLLOWING
\mathbf{C}
         VARIABLES AFTER STUDYING THE COMMENTS PLACED THROUGHOUT THE MAIN
                                                                                                                   000019
\mathbf{C}
         SEGMENT MXSOS2. CORRESPONDING DIMENSIONS MUST BE DECLARED IN ALL
                                                                                                                   000020
         SUBROUTINES EXCEPT FOR THE MMLC PACKAGE.
                                                                                                                   000021
                                                                                                                   000022
         REAL X(45), W(20000), B(1), C(1,1), T(3), DISP(16), Q0(16)
REAL OMEGA(47), SURL(47), SLRL(47), WURL(47), WLRL(47),
SU(20,16), SL(20,16), WU(20,16), WL(20,16)
                                                                                                                   000023
                                                                                                                   000024
                                                                                                                   000025
         INTEGER RLSCODE(47), SPCODE(20, 16), CHBCODE(16,2)
REAL WO(16), BW(16), CM(16,8,8), PN1(16), PN2(16), SPN1(16), SPN2(16),
                                                                                                                   000026
                                                                                                                  000027
                                                                                                                   aaaaen
                       GL(16), WGL(16), DIA(16)
         INTEGER CEL(16,8,8)
REAL FCNST(16), LAMRES(16), LAMDEL(16)
REAL DRL(100), FIL(16), DIL(16,100)
REAL ANGLE1(16), ANGLE2(16), GRDEL(16)
                                                                                                                   000029
                                                                                                                   000030
                                                                                                                   000031
                                                                                                                   000032
         INTEGER IR(16), IRT(16), IPN1(16), IPN2(16), IWG(16)
INTEGER LC(16,36), KC(16,36)
                                                                                                                  000033
                                                                                                                  000034
         EXTERNAL FDF2
                                                                                                                  000035
         COMMON /BLK1/WO, BW, PN1, PN2, GL, VS, RS, P12, WIDTH, NP1
                                                                                                                  000036
         COMMON /BLK2/CM, WGL
                                                                                                                   000037
         COMMON BLK3/OMEGA, SURL, SLRL, WURL, WLRL, SU, SL, WU, WL, RLSCODE, SPCODE, NCOUNT, MODE, NCH, MO, NFREQ, NFRL,
                                                                                                                   000038
                                                                                                                  000039
                                                                                                                  000040
                    CHBCODE, IFLAGJS, IFLAGDP, IDISPER
         COMMON /BLK4/CBR, FCUT
                                                                                                                   000041
         COMMON /BLK5/DISP
                                                                                                                   000042
         COMMON/BLK6/FCNST, LAMRES, LAMDEL
                                                                                                                   000043
                                                                                                                   000044
         COMMON/BLK7/CEL
         COMMON/BLKB/IR, IRT, IPN1, IPN2, IWG, LC, KC
                                                                                                                   000045
                                                                                                                   000046
         DATA T/10HMULTIPLEXE, 10HR PROBLEM , 10HMXTST6C
                                                                                                                   000047
         THE MXSOS2 PACKAGE CAN OPERATE IN THREE MODES: SIMULATION, SENSITI
                                                                                                                   000048
CCC
         VITY ANALYSIS AND OPTIMIZATION. TO SELECT THE REQUIRED FUNCTION OF
                                                                                                                   000049
         THE PACKAGE SET LMODE TO
                                                                                                                   000050
         1 - IF MULTIPLEXER SIMULATION IS REQUIRED,
2 - IF MULTIPLEXER SENSITIVITY ANALYSIS IS REQUIRED.
                                                                                                                   000051
\mathbf{c}
                                                                                                                   000052
C
Ĉ
         3 - IF MULTIPLEXER OPTIMIZATION IS REQUIRED.
                                                                                                                   000053
                                                                                                                   000054
C
         SELECT MODE OF OPERATION OF THE PACKAGE
                                                                                                                   000055
                                                                                                                   000056
C
                                                                                                                   000057
         LMODE=2
                                                                                                                   666658
C
         THIS PART OF THE MAIN SEGMENT IS USED TO DEFINE THE DATA FOR
                                                                                                                   000059
C
         MULTIPLEXER SIMULATION. IT MUST ALWAYS BE DEFINED, REGARDLESS OF THE MODE OF OPERATION OF THE PACKAGE SELECTED.
                                                                                                                   000060
\mathbf{C}
                                                                                                                   000061
\mathbf{C}
                                                                                                                   000062
C
                      NUMBER OF FILTER CHANNELS INCLUDING DUMMY CHANNELS
                                                                                                                   000063
\mathbf{C}
         NCH
                      ORDER OF FILTERS(THE SAME FOR ALL FILTERS, ODD OR EVEN)
                                                                                                                   000064
Č
         MO
                    - VECTOR OF CENTER FREQUENCIES IN MHZ, ONE PER CHANNEL
                                                                                                                   000065
         WO
```

Fig. 1 Listing of MXSOS2 arranged for sensitivity analysis.

```
- VECTOR OF UNLOADED Q FOR THE FILTERS, ONE PER CHANNEL - VECTOR OF FILTER DIAMETERS IN INCHES, ONE PER CHANNEL - VECTOR OF CHANNEL BANDWIDTHS IN MHZ, ONE PER CHANNEL - VECTOR OF INPUT TRANSFORMER RATIOS(SQUARED), ONE PER
        Q0
                                                                                                  000066
C
                                                                                                  000067
        DIA
C
                                                                                                  000068
        BW
                                                                                                  000069
        SPN1
                                                                                                  000070
                    CHANNEL
        SPN2
                    VECTOR OF OUTPUT TRANSFORMER RATIOS(SQUARED), ONE PER
                                                                                                  000071
Ċ
                                                                                                  000072
                    CHANNEL
                 - VECTOR OF CHANNEL TERMINATING CONDUCTANCES, ONE PER
                                                                                                  000073
\mathbf{c}
        GL
                                                                                                  000074
                    CHANNEL
                 - SYMMETRICAL MATRIX OF COUPLING PARAMETERS (CHANNEL, ROW,
                                                                                                  000075
        CM
                    COLUMN), INCLUDING NONZERO DIAGONAL ELEMENTS TO MODEL
                                                                                                  000076
                    ASYNCHRONOUS DESIGNS
                                                                                                  000077
Č
        CEL
                 - SYMMETRICAL MATRIX FOR TYPE OF COUPLING,
                                                                         +1 FOR SCREW.
                                                                                                  000078
                    -1 FOR IRIS, CORRESPONDING TO CM AS ABOVE
                                                                                                  000079
                 - VECTOR OF WAVEGUIDE SPACINGS FOR EACH CHANNEL, MEASURED IN INCHES ALONG THE MANIFOLD FROM THE ADJACENT CHANNEL (DISTANCE FROM THE SHORT CIRCUIT FOR THE FIRST CHANNEL)
        WCL
                                                                                                  000080
                                                                                                  000081
\mathbf{c}
                                                                                                  000082
                 - SOURCE VOLTAGE AT THE COMMON PORT
- SOURCE RESISTANCE AT THE COMMON PORT
C
                                                                                                  68666
        VS
                                                                                                  000084
        RS
                - CONSTANT EQUAL TO TWICE PI
- MANIFOLD WIDTH IN INCHES
       P12
                                                                                                  000085
        WIDTH
                                                                                                  000086
                                                                                                  000087
        DEFINE THE NUMBER OF CHANNELS AND THE ORDER OF THE FILTERS
                                                                                                  000088
                                                                                                  000089
        NCH=3
                                                                                                  000090
        M0=6
                                                                                                  000091
        NP1=NCH+1
                                                                                                  000092
                                                                                                  000093
\mathbf{C}
        DEFINE CENTER FREQUENCIES IN MHZ
                                                                                                  000094
                                                                                                  000095
\mathbf{C}
                                                                                                  000096
        WO(1) = 12060.0
        WO(2) = 12020.0
                                                                                                  000097
        WO(3) = 11980.0
                                                                                                  000098
                                                                                                  000099
\mathbf{C}
        DEFINE UNLOADED Q FACTORS OF THE FILTERS
                                                                                                  000100
                                                                                                  000101
                                                                                                  000102
        DO 5 1=1,NCH
        QO(1)=12000.0
                                                                                                  000103
     5 CONTINUE
                                                                                                  000104
                                                                                                  000105
\mathbf{C}
        DEFINE THE DIAMETER OF THE FILTERS IN INCHES
                                                                                                  000106
                                                                                                  000107
        DO 70 I=1,NCH
                                                                                                  000108
       DIA(I) = 1.07
                                                                                                  000109
   70 CONTINUE
                                                                                                  000110
                                                                                                  000111
C
        DEFINE BANDWIDTHS, INPUT/OUTPUT TRANSFORMER RATIOS AND OUTPUT
                                                                                                  000112
\mathbf{c}
                                                                                                  000113
C
                                                                                                  000114
       DO 1 I=1, NCH
BW(I)=39.5
                                                                                                  000115
                                                                                                  000116
                                                                                                  000117
        CL(I) = 1.0
       SPN1(I) = 0.69967
                                                                                                  000118
       SPN2(I)=1.09450
                                                                                                  000119
       PN1(I)=SQRT(SPN1(I))
                                                                                                  000120
                                                                                                  000121
       PN2(1) = SQRT(SPN2(1))
     1 CONTINUE
                                                                                                  000122
                                                                                                  000123
        DEFINE THE SYMMETRICAL COUPLING MATRIX. ONLY THE UPPER PART OF THE
                                                                                                  000124
        CM MATRIX HAS TO BE DEFINED.
                                                                                                  000125
                                                                                                  000126
                                                                                                  000127
        DO 30 I=1, NCH
       DO 30 J=1, MO
DO 30 KK=1, MO
                                                                                                  000128
                                                                                                  000129
                                                                                                  000130
       CM(I, J, KK) = 0.0
```

Fig. 1 (continued) Listing of MXSOS2 arranged for sensitivity analysis.

```
000131
   30 CONTINUE
                                                                                           000132
       DO 2 1=1,NCH
                                                                                           000133
       CM(I,1,2) = 0.59395
                                                                                           000134
       CM(1,2,3) = 0.53514
                                                                                           000135
       CM(1,3,4) = 0.42471
                                                                                           000136
       CM(1,3,6)=-0.39967
                                                                                           000137
       CM(1,4,5) = 0.83371
                                                                                           000138
       CM(1,5,6) = 0.76313
                                                                                           000139
    2 CONTINUE
                                                                                           000140
\mathbf{c}
                                                                                           000141
       DEFINE THE TYPE OF COUPLING IN THE FILTER
                 +1 >> SCREW COUPLING
                                           -1 >> IRIS COUPLING
                                                                                           000142
_{\mathbf{C}}^{\mathbf{C}}
                                                                                           000143
                                                                                           000144
       DO 71 I=1, NCH
                                                                                           000145
       DO 71 J=1, MO
DO 71 KK=1, MO
                                                                                           000146
                                                                                           000147
       CEL(1,J,KK)=0
                                                                                           000148
   71 CONTINUE
                                                                                           000149
C
                                                                                           000150
       DO 72 I=1,NCH
                                                                                           000151
       CEL(I,1,2)=1
CEL(I,2,3)=-1
CEL(I,3,4)=1
                                                                                           000152
                                                                                           000153
                                                                                           000154
       CEL(I,3,6) = -1
                                                                                           000155
       CEL(1,4,5) = -1
                                                                                           000156
       CEL(I, 5, 6) = 1
                                                                                           000157
\mathbf{C}
                                                                                           000158
       DO 72 J=1.MO
                                                                                           666159
       DO 72 KK=1,J
                                                                                           000160
       CEL(I,J,KK) = CEL(I,KK,J)
                                                                                           000161
    72 CONTINUE
                                                                                           000162
\mathbf{C}
       DEFINE THE SECTION LENGTHS (SPACINGS ALONG THE WAVEGUIDE MANIFOLD)
                                                                                           000163
C
                                                                                           000164
C
                                                                                           000165
       WGL(1) = 0.641
                                                                                           000166
       WGL(2) = 0.631
                                                                                            000167
        WGL(3)=0.633
                                                                                            000168
\mathbf{C}
       DEFINE SOME CONSTANTS, SOURCE VOLTAGE, SOURCE RESISTANCE, TWICE PI
                                                                                           000169
\mathbf{c}
                                                                                           000170
       MANIFOLD WIDTH
\mathbf{c}
                                                                                           000171
C
                                                                                            000172
       VS=1.0
                                                                                            000173
       RS=1.0
                                                                                            000174
       P12=8.0*ATAN(1.0)
                                                                                            000175
       WIDTH=0.75
                                                                                           000176
C
        THE MXSOS2 PACKAGE CAN EXPLOIT THREE PRACTICAL MODELS OF THE
                                                                                           000177
       MULTIPLEXER AS DETERMINED BY THE PARAMETERS IFLAGJS, IFLAGDP
                                                                                           000178
C
                                                                                            000179
C
       AND IDISPER.
                                                                                            000180
CC
                                                                                            000181
        IFLAGJS
       0 - IF JUNCTIONS ARE IDEAL
1 - IF JUNCTIONS ARE NONIDEAL
                                                                                            000182
                                                                                            000183
CC
                                                                                            000184
                                                                                            000185
        IFLAGDP
       0 - IF FILTERS ARE LOSSLESS
1 - IF FILTERS ARE LOSSY
                                                                                            000186
C
                                                                                            000187
                                                                                            000188
CCC
                                                                                            000189
        IDISPER
        0 - IF FILTERS ARE DISPERSIVE
1 - IF FILTERS ARE NONDISPERSIVE
                                                                                            000190
                                                                                            000191
C
                                                                                            000192
\mathbf{C}
                                                                                            000193
        FLAG FOR JUNCTION SUSCEPTANCE (SET TO 0 OR 1)
C
                                                                                            000194
                                                                                            000195
        IFLACJS=1
```

Fig. 1 (continued) Listing of MXSOS2 arranged for sensitivity analysis.

```
IF(IFLAGJS.NE.1)GO TO 42
                                                                                                            000196
\mathbf{C}
                                                                                                            000197
         CALL CONSTICWIDTH)
                                                                                                            000198
\mathbf{c}
                                                                                                            000199
    42 CONTINUE
                                                                                                            000200
C
                                                                                                            000201
         FLAC FOR FILTER DISSIPATION (SET TO 0 OR 1)
                                                                                                            000202
\mathbf{C}
                                                                                                            000203
         IFLACDP=1
                                                                                                            000204
         IF(IFLAGDP.NE.1)GO TO 43
                                                                                                            000205
C
                                                                                                            000206
         CALL DISPAT(NCH, WO, BW, QO)
                                                                                                            000207
                                                                                                            000208
C
    43 CONTINUE
                                                                                                            000209
                                                                                                            000210
C
         FLAG FOR DISPERSIVE EFFECTS IN THE COUPLED CAVITY FILTERS
C
                                                                                                            000211
C
         (SET TO Ø OR 1)
                                                                                                            000212
C
                                                                                                            000213
         IDISPER= 1
                                                                                                            000214
         IF(IDISPER.NE.1)GO TO 44
                                                                                                            000215
\mathbf{c}
                                                                                                            000216
         CALL DISPER(NCH, WO, BW, DIA)
                                                                                                            000217
                                                                                                            000218
C
    44 CONTINUE
                                                                                                            000219
C
                                                                                                            000220
         CHECK WHETHER THE SIMULATION MODE IS REQUIRED
C
                                                                                                            000221
C
                                                                                                            000222
         IF(LMODE.NE.1)GO TO 16
                                                                                                            000223
C
                                                                                                            000224
                                                                                                            000225
CC
        SENSITIVITY ANALYSIS, CORRESPONDING TO LMODE=2
                                                                                                            000226
                                                                                                            000227
        THIS PART OF THE MAIN PROGRAM IS USED TO DEFINE CODES FOR MULTI-PLEXER PARAMETERS W.R.T. WHICH WE WANT TO FIND THE SENSITIVITIES.
                                                                                                            000228
00000000
                                                                                                            000229
         THE PARAMETER IR(I)=0 SIGNIFIES THAT NO ELEMENTS OF THE FILTER
                                                                                                            000230
        COUPLING MATRICES ARE OPTIMIZATION VARIABLES. SUBROUTINE "SIMGRD2" IS CALLED AT EACH FREQUENCY DEFINED IN THE VECTOR
                                                                                                            000231
                                                                                                            000232
        OMEGA(1).
                                                                                                            000233
                                                                                                            000234
                   - VECTOR CONTAINING THE NUMBER OF COUPLING PARAMETERS BE-
                                                                                                            000235
                    ING VARIABLES FOR EACH CHANNEL
MATRIX CONTAINING THE ROW INDICES OF COUPLING PARAMETERS
000000000000
                                                                                                            000236
        LC
                                                                                                            000237
                      BEING VARIABLES FOR EACH CHANNEL
                                                                                                            000238
                     MATRIX CONTAINING THE COLUMN INDICES OF COUPLING PARAMETERS BEING VARIABLES FOR EACH CHANNEL
INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING
WHETHER THE INPUT TRANSFORMER RATIO IS AN OPTIMIZATION
        KC
                                                                                                            000239
                                                                                                            000240
         IPN1
                                                                                                            000241
                                                                                                            000242
                     VARIABLE (IPN1(I)=1) OR NOT (IPN1(I)=0).
INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING
                                                                                                            000243
         IPN2
                                                                                                            000244
                     WHETHER THE OUTPUT TRANSFORMER RATIO IS AN OPTIMIZATION VARIABLE (IPN2(I)=1) OR NOT (IPN2(I)=0).

INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING WHETHER THE WAVEGUIDE SECTION LENGTH IS AN OPTIMIZATION VARIABLE (IWG(I)=1) OR NOT (IWG(I)=0).

VECTOR OF ARBITRARY FREQUENCIES (EXCEPT CENTER FREQUENCIES) AT UNION THE SEMESTER VARIABLE (IWG ID BE DEPENDED.
                                                                                                            000245
                                                                                                            000246
0000
         IWG
                                                                                                            000247
                                                                                                            000248
                                                                                                            000249
        OMEGA
                                                                                                            000250
00000000
                      CIES) AT WHICH THE SENSITIVITY ANALYSIS IS TO BE PERFOR-
                                                                                                            000251
                      MED.
                                                                                                            000252
        FRSNS
                  - ACTUAL FREQUENCY AT WHICH THE SUBROUTINE "SIMGRD" IS
                                                                                                            000253
                                                                                                            000254
                     CALLED
                     TOTAL NUMBER OF VARIABLES W.R.T. WILLOH THE SENSITIVITIES
        NV
                                                                                                            000255
                      ARE REQUIRED
                                                                                                            000256
        FRL
                   - VALUE OF THE COMMON PORT RETURN LOSS IN DB AT THE FREQU-
                                                                                                            000257
                     ENCY FRSNS
                                                                                                            000258
č
                     SENSITIVITIES OF THE COMMON PORT RETURN LOSS W.R.T. ALL
        DRL
                                                                                                            000259
                      VARIABLES
                                                                                                            000260
```

Fig. 1 (continued) Listing of MXSOS2 arranged for sensitivity analysis.

```
- VECTOR OF THE INSERTION LOSS FUNCTION IN DB FOR EACH
                                                                                         000261
       FIL
\mathbf{C}
                 CHANNEL AT THE FREQUENCY FRSNS
MATRIX OF SENSITIVITIES OF THE INSERTION LOSS FUNCTION
                                                                                         000262
                                                                                         000263
C
       DIL
                                                                                         000264
\mathbf{C}
                  FOR EACH CHANNEL W.R.T. ALL VARIABLES
C
                                                                                         000265
       DEFINE THE NUMBER OF COUPLING VARIABLES PER CHANNEL
                                                                                         000266
C
                                                                                         000267
                                                                                         000268
    16 CONTINUE
                                                                                         000269
       IR(1) = 12
                                                                                         000270
       IR(2) = 12
                                                                                         000271
       IR(3) = 12
                                                                                         000272
\mathbf{C}
C
       DEFINE CODES TO IDENTIFY VARIABLES FOR INPUT-OUTPUT TRANSFORMER
                                                                                         000273
       RATIOS AND WAVEGUIDE SPACINGS
                                                                                         000274
                                                                                         000275
                                                                                         000276
       DO 55 I=1, NCH
       1WG(1) = 1
                                                                                         000277
                                                                                         000278
       IPN1(I)=1
       IPN2(I)=1
                                                                                         000279
                                                                                         000280
   55 CONTINUE
                                                                                         000281
\mathbf{C}
       EVALUATE THE TOTAL NUMBER OF VARIABLES ACCUMULATED AFTER
                                                                                         000282
\mathbf{c}
                                                                                         000283
\mathbf{C}
       EACH SECTION
                                                                                         000284
\mathbf{C}
       CALL TOTAL2(NCH, IR, IRT, IPN1, IPN2, IWG)
                                                                                         000285
                                                                                         000286
C
       DEFINE CODES FOR THE VARIABLES CONTAINED IN THE COUPLING MATRICES
                                                                                         000287
\mathbf{C}
                                                                                         000288
                                                                                         000289
       DO 127 I=1,3
       LC(I,1)=1
LC(I,2)=1
                                                                                         000290
                                                                                         000291
                                                                                         000292
       LC(1,3)=2
                                                                                         000293
       LC(I,4)=2
       LC(1,5)=3
                                                                                         000294
       LC(1,6)=3
LC(1,7)=3
                                                                                         000295
                                                                                         000296
                                                                                         000297
       LC(I,8)=4
                                                                                         000298
       LC(1,9)=4
                                                                                         000299
       LC(I, 10) = 5
                                                                                         000300
       LC(1,11)=5
                                                                                         000301
       LC(I, 12)=6
       KC(1,1)=1
KC(1,2)=2
                                                                                         000302
                                                                                         000303
       KC(1,3)=2
KC(1,4)=3
                                                                                         000304
                                                                                         000305
       KC(I,5)=3
KC(I,6)=4
KC(I,7)=6
                                                                                         000306
                                                                                         000307
                                                                                         000308
                                                                                         000309
       KC(1,8)=4
                                                                                         000310
       KC(I,9)=5
                                                                                         000311
       KC(I, 10) = 5
       KC(I, II) = 6
                                                                                         000312
       KC(1, 12) = 6
                                                                                         000313
                                                                                         000314
  127 CONTINUE
                                                                                         000315
\mathbf{C}
       CHECK WHETHER THE SIMULATION AND SENSITIVITY ANALYSIS MODE
                                                                                         000316
C
C
       IS REQUIRED
                                                                                         000317
C
                                                                                         000318
       IF(LMODE.NE.2) CO TO 17
                                                                                         000319
                                                                                         000320
C
       CENERATE FREQUENCY POINTS IN MHZ
                                                                                         000321
                                                                                         000322
                                                                                         000323
       NFREQ=3
                                                                                         000324
       OMEGA(1) = 12062.0
       OMEGA(2) = 12022.0
                                                                                         000325
```

Fig. 1 (continued) Listing of MXSOS2 arranged for sensitivity analysis.

```
000326
          OMEGA(3) = 11982.0
                                                                                                                              000327
          NCHAN=NCH
                                                                                                                              000328
          MORDER= MO
DO 18 ICOUNT= 1, NFREQ
                                                                                                                              000329
                                                                                                                              000330
          FRSNS=OMEGA(ICOUNT)
                                                                                                                              000331
\mathbf{C}
          CALL SIMGRD2(FRSNS, FRL, DRL, FIL, DIL, NCHAN, MORDER, ICOUNT, IFLAGJS, IFLAGDP, IDISPER)
                                                                                                                              000332
                                                                                                                              000333
                                                                                                                              000334
C
                                                                                                                              000335
          WRITE(6,800) FRSNS
           FORMAT(//7X, "FREQUENCY = ",F10.3/)
                                                                                                                              000336
  800 FORMAT(//7x, "FREQUENCY = ",F10.3/)
WRITE(6,810)
810 FORMAT(7x, "RETURN LOSS",3(5x," INSERTION "),/
1 23x," LOSS CHN1 ",5x," LOSS CHN2 ",5x," LOSS CHN3 ",//)
DO 830 I=1,45
WRITE(6,820) I,DRL(I),(DIL(J,I),J=1,3)
820 FORMAT(1x,13,2x,4(E13.7,3x)/)
830 CONTINUE
18 CONTINUE
   800
                                                                                                                              000337
                                                                                                                              000338
                                                                                                                              000339
                                                                                                                              000340
                                                                                                                              000341
                                                                                                                              000342
                                                                                                                              000343
                                                                                                                              000344
     18 CONTINUE
17 CONTINUE
                                                                                                                              000345
                                                                                                                              000346
          STOP
                                                                                                                              000347
          END
```

Fig. 1 (continued) Listing of MXSOS2 arranged for sensitivity analysis.

	FREQUENCY =	12062.000		
	RETURN LOSS	INSERTION	INSERTION	INSERTION
	Ideal Olds Troops	LOSS CHN1	LOSS CHN2	LOSS CHN3
		2000		
1	3519404E+02	.8961685E+00	.2753685E+01	.4634337E+ 0 1
$\tilde{2}$	2595370E+02	.2085088E+00	1326312E+02	1174383E+02
3	.4771767E+02	1147921E+01	1463513E+01	4033040E+01
4	.9675811E+01	5768095E+00	.1455436E+02	. 1390475E+02
5	4269060E+02	. 1047668E+01	.4166345E+00	.2723190E+01
6	.1767393E+01	1739167E+00	8878407E+01	8897179E+01
7	7377125E+01	.5807486E+00	.9392055E+01	.9709946E+01
8	.1765466E+02	4018802E+00	.2534749E+00	7040857E+00
9	5142400E+01	1782476E-01	.4286271E+01	.4527437E+01
10	9866458E+01	.2483579E+00	4228866E+00	.1146891E+00
11	.8091632E+01	1780651E+00	4462083E+01	4861322E+01
12	. 1921909E+02	4536889E+00	.8852856E+00	1624025E+00 .7483993E+01
13	.2808763E+02	7836352E+00	.9082565E+01	.7483993E+01
14	1221682E+02	.2423505E+00	.6517218E+01	1570727E+02
15	. 1119741E+03	2845380E+01	9732153E+01 .4323698E+01	3996365E+00
16	.4735677E+01	1446217E+00	1719847E+02	.2449359E+00
17	2820654E+01	.9310488E-01	. 4782688E+01	3776016E-01
18	.4228542E+00	1500772E-01 .9181533E-02	1883435E+02	.2149942E-01
19	2290972E+00 .3079065E-01	1376970E-02	. 4741956E+01	3031256E-02
20	1332824E-01	.4856780E-03	.2357284E+01	. 1202718E-02
21 22	.6875508E-02	1176946E-02	.2763118E+02	1538818E-02
23	.1448850E-02	4103929E-04	7275892E+00	1190872E-03
24	5954572E-03	5278727E-04	.2500924E+01	2010762E-04
$\frac{24}{25}$.2953330E-04	.1178987E-04	4250901E+00	. 1008963E-04
26	.4912742E-03	8191612E-05	3925802E+00	3470555E-04
27	. 1613312E-03	1219991E-03	.3519750E+01	1296731E-03
28	2206056E+02	.6211138E+00	9762958E+01	. 1809523E+01
29	.1577621E-02	.4982725E-04	3538580E+01	3597565E-04
30	5705633E+01	. 1440959E+00	.6426574E+00	.9458484E+00
31	. 1012517E+01	2830083E-01	2830083E-01	.2121870E+01
32	2930252E+00	.8499031E-02	.8499031E-02	1523696E+02
33	.2149101E-01	6459243E-03	6459243E-03	.2187578E+01
34	5771667E-02	.1817344E-03	. 1817344E-03	1681766E+02
35	.3822295E-03	1258114E-04	1258114E-04	.2185606E+01
36	7829787E-04	.2537537E-05	. 2537537E-05	.4236703E+00
37	.7209554E-04	5549194E-05	5549194E-05	.2305336E+02 6727889E-01
38	.4064799E-05	1296748E-06	1296748E-06 5096539E-07	.4500352E+00
39	3009996E-06	5096539E-07	5096539E-07	1960763E-01
40	3010533E-08	.2735101E-08	.2735101E-08 .2607968E-07	2809897E+00
41	.3624496E-06	.2607968E-07 3856550E-06	-, 3856550E-06	. 2038193E+01
42	.3104291E-05	3856550E-06 .2627051E+00	.2627051E+00	1012137E+02
43	9767977E+01	.8820953E-06	. 8820953E-06	7090034E+01
44		. 2346737E+00	.2346737E+00	9945607E+01
45	8690840E+01	, 2070 (O(DT00	· MUTUS US LINU	0,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,

Fig. 2 Results of the three-channel sensitivity analysis problem.

	FREQUENCY =	12022.000		
	RETURN LOSS	INSERTION	INSERTION	INSERTION
	IBIOIR BOOK	LOSS CHN1	LOSS CHN2	LOSS CIIN3
		2000 02212		
1	8938535E+01	4638673E+01	.3647777E-01	2600154E+ 0 0
2	-,5706447E+01	1774849E+02	.3459453E-01	1662947E+00
3	9016115E+00	5433870E+01	.7476605E-02	2632742E-01
4	4780550E+00	1948497E+02	.6313271E-02	1402139E-01
5	6259816E-01	5386128E+01	.1227717E-02	1846593E-02
6	3994179E-01	.3271034E+01	.3365164E-03	1166456E-02
7	3988235E-01	.2939090E+02	1932505E-02	1104853E-02
8	5976587E-02	.1123113E+01	.8391596E-05	1734323E-03
9	8372691E-02	.3529402E+01	1646502E-03	2383084E-03
10	1462041E-02	.7468514E+00	3868933E-04	4135120E-04
11	.1755534E-02	1171976E+00	1665343E-04	.5131761E-04
12	,6866322E-02	3702453E+01	.2224542E-03	. 1931260E-03
13	3891205E+02	8842719E+01	.9181233E-01	1130155E+01
14	.8597621E-02	-,2471830E+01	.9186842E-04	.2467480E-03
15	2054311E+03	.7450036E+01	.1652422E+00	5958076E+01
16	.6167365E+02	3354280E+00	6086830E-01	.1796251E+01
17	4763673E+03	1342368E+02	.1895081E-01	1345161E+02
18	6152977E+01	.2411308E+01	.7396638E-01	2419590E+00
19	.5055721E+03	. 1328559E+02	8279873E+00	.1430165E+02
20	2495477E+02	2926610E+01	1472336E-01	6459931E+00
21	3014046E+03	7515053E+01	. 1688113E+00	8536850E+01
22	.3138117E+03	.7526460E+01	.8204542E-01	.8896126E+01
23	.2485572E+02	. 1577416E+01	.2303519E-01	.6787286E+00
24	. 1415924E+03	.3298357E+01	2879527E+00	.4016524E+01
25	2349311E+02	1124075E+01	.2028166E-01	6512019E+00
26	1448973E+03	3223067E+01	.1708311E+00	4114290E+01
27	.4786680E+02	.2242742E+01	1158789E-01	. 1328067E+01 . 9463690E+01
28	.3356340E+03	.9984863E+01	3992084E+00	.9463690E+01
29	.2112683E+03	.4676843E+01	2769331E+00	6827856E+01
30	2353287E+03	8600616E+01	.2904115E+00	0027030E+01
31	5878510E+00	2402860E-01	2402860E-01	1726990E+02
32	.6102327E+00	.2167673E-01	.2167673E-01 4359952E-02	.4793404E+01
33	1306936E+00	4359952E-02	.3474686E-02	1884019E+02
34	. 1100973E+00	.3474686E-02	6184035E-03	.4742796E+01
35	2014408E-01	6184035E-03	. 1505014E-03	.2356995E+01
36	.4581208E-02	. 1505014E-03	1060310E-02	.2763148E+02
37	3706725E-01	1060310E-02 3877884E-05	3877884E-05	7275628E+00
38	5717165E-04	3877884E-05 7229326E-04	7229326E-04	.2500894E+01
39	2585893E-02	-,7229326E-04 .1331450E-04	. 1331450E-04	4250381E+00
40	.4718398E-03	.1331430E-04 .4759705E-05	. 4759705E-05	3927882E+00
41	. 1951475E-03	1249929E-03	1249929E-03	.3519953E+01
42	4405361E-02 .7751258E+00	1249929E-03 .5634120E-01	.5634120E-01	-,1032773E+02
43	.7751250E+00 .3477530E-02	.9600908E-04	.9600908E-04	3538636E+01
44 45	.3477330E-02 .3822605E+03	3852653E+00	3852653E+00	. 1077355E+02
40	, 30220002703	.00020001.00	.000=000=.00	

Fig. 2 (continued) Results of the three-channel sensitivity analysis problem.

	FREQUENCY =	11982.000		
	RETURN LOSS	INSERTION	INSERTION	INSERTION
	IEITOIA EOE	LOSS CHN1	LOSS CHN2	LOSS CHN3
		2022 412.1		•
1	1021814E+01	2060321E+ 0 1	.9765237E- 0 1	.2785507E-01
$\hat{2}$	3150864E+00	1525917E+02	.3046251E-01	.8932318E-02
3	2397585E-01	2274935E+01	.2344674E- 02	.7058057E-03
4	6505257E-02	1684870E+02	.6461660E- 03	.2012852E-03
5	4469836E-03	2274755E+01	.4508676E-04	.1450375E-04
6	-,9777687E-04	.4739968E+00	.9803486E- 05	.3114773E-05
7	.7892172E-04	.2317703E+02	1193061E-04	6445611E-05
8	5278142E-05	.7800556E-01	.5260152E-06	. 1650168E-06
9	5296567E-06	.5021415E+00	3103552E-07	6546439E-07
10	1233507E-08	,2337036E-01	3780091E-08	3780782E-08
11	.5673644E-06	3068098E+00	5604874E-08	.3210796E-07
12	3205749E-05	2111599E+01	.6886469E-06	.4614755E-06
13	9488021E+01	8749858E+01	.8961758E+00	.2483019E+00
14	.5262981E-05	6992219E+01	.6618839E-06	.9964111E-06
15	1068917E+03	. 1828916E+02	.9977267E+01	.2680897E+01
16	5291011E+01	.5236022E+00	4592216E+01	. 1618029E+00
17	3571121E+01	.3636518E+00	1765637E+02	. 1192388E+00
18	5985942E+00	.6267992E-01	5418371E+01	.2167425E-01
19	3575269E+00	.3933874E-01	1947562E+02	. 1480621E-01 . 2504609E-02
20	5366981E-01	.6193465E-02	5384701E+01	.9669481E-03
21	2660820E-01	.2789774E-02	.3271788E+01	-, 2237204E-02
22	. 1220231E-01	3112435E-02	.2939069E+ 02 .1123178E+ 0 1	.8541389E-04
23	3264219E-02	.3083055E-03	.3529341E+01	1293807E-03
24	1557823E-02	2673494E-04	. 7467257E+00	3662097E-04
25	1021483E-03	3050680E-04 1274419E-03	1176303E+00	4510863E-04
26	. 1201373E-02	1274419E-03 .2491932E-03	3702693E+01	. 2295064E-03
27	2164931E-03 2188860E+02	.2491932E=03 .2105394E+01	8278678E+01	.6099536E+00
28	2188800E+02	1733443E-03	2472128E+01	.2381207E-04
29 30	1087422E+03	. 1153238E+02	. 1015720E+02	.2734358E+01
30 31	. 3881417E+02	-, 1266533E+01	1266533E+01	9924119E+00
32	1984458E+02	-, 1338578E+02	1338578E+02	.6057205E-01
33	4544877E+02	.3567410E+01	.3567410E+01	. 1228414E+01
34	.3787113E+02	.1281777E+02	. 1281777E+02	1299115E+01
35	.3784055E+02	3919085E+01	3919085E+01	1006219E+01
36	2966867E+02	7055742E+01	7055742E+01	.6320069E+00
37	.3610376E+02	.6915447E+01	.6915447E+01	5343410E+00
38	1430177E+02	. 1968049E+01	. 1968049E+01	.4127896E+00
39	. 1799776E+02	.2979163E+01	.2979163E+01	6086355E+00
40	.7102750E+01	1329338E+01	1329338E+01	1842857E+00
41	2108300E+02	2828455E+01	2828455E+01	.5675335E+00
42	1363996E+02	.2639771E+01	.2639771E+01	.3838579E+00
43	.4768819E+01	.1019229E+02	. 1019229E+ 02	1917864E+00
44	.3113555E+02	.4091332E+01	.4091332E+01	8653616E+00
45	1323121E+03	7037096E+01	7037096E+01	.3459646E+01

Fig. 2 (continued) Results of the three-channel sensitivity analysis problem.

MULTIPLEXER OPTIMIZATION: FORMAL DESCRIPTION

General Description

The third part of the main segment is used to define all variables and arrays for multiplexer optimization. To select the multiplexer parameters which are the optimization variables the matrices LC and KC have to be used, as described in the sensitivity analysis part SENSITIVITY.

Three modes of optimization are allowed. To select the desired mode of optimization, the user must set the parameter MODE to

- o if only common port return loss optimization is required,
- 1 if only insertion loss optimization is required,
- 2 if both return loss and insertion loss optimization are required.

In each case, a different header for the printout of optimization results can be obtained by calling the subroutine MMXHDR (part of the MMLC package [1]) for which the argument T can be defined using the DATA statement. Values of the optimization variables at the starting point must be supplied by defining the X vector using either the DATA statement or explicitly.

Formulation of the Problem

The design of a contiguous-band multiplexer structure is formulated as a minimax optimization problem [2, 3]. The objective function to be minimized is given by

$$F(\mathbf{x}) = \max_{j \in J} f_j(\mathbf{x}), \tag{1}$$

where \mathbf{x} is a vector of optimization variables (e.g., section or spacing lengths, channel input and output couplings and filter coupling parameters) and $\mathbf{J} \triangleq \{1, 2, ..., m\}$ is an index set. The minimax functions $\mathbf{f}_j(\mathbf{x}), j \in J$, can be of the form [2, 3]

$$\mathbf{w}_{\mathbf{U}\mathbf{k}}^{1}(\omega_{i})(\mathbf{F}_{\mathbf{k}}^{1}(\mathbf{x},\omega_{i}) - \mathbf{S}_{\mathbf{U}\mathbf{k}}^{1}(\omega_{i})), \tag{2}$$

$$-\mathbf{w}_{\mathrm{Lk}}^{1}(\boldsymbol{\omega}_{i})(\mathbf{F}_{k}^{1}(\mathbf{x},\boldsymbol{\omega}_{i})-\mathbf{S}_{\mathrm{Lk}}^{1}(\boldsymbol{\omega}_{i})), \tag{3}$$

$$\mathbf{w}_{\mathbf{U}}^{2}(\boldsymbol{\omega}_{i})(\mathbf{F}^{2}(\mathbf{x},\boldsymbol{\omega}_{i}) - \mathbf{S}_{\mathbf{U}\mathbf{k}}^{2}(\boldsymbol{\omega}_{i})), \tag{4}$$

$$-\mathbf{w}_{L}^{2}(\omega_{i})(\mathbf{F}^{2}(\mathbf{x},\omega_{i})-\mathbf{S}_{L}^{2}(\omega_{i})), \tag{5}$$

where $F_k^{\ 1}(\mathbf{x},\omega_i)$ is the insertion loss for the kth channel at the ith frequency, $F^2(\mathbf{x},\omega_i)$ is the return loss at the common port at the ith frequency, $S_{Uk}^{\ 1}(\omega_i)(S_{Lk}^{\ 1}(\omega_i))$ is the upper (lower) specification on insertion loss of the kth channel at the ith frequency, $S_U^{\ 2}(\omega_i)(S_L^{\ 2}(\omega_i))$ is the upper (lower) specification on return loss at the ith frequency, and $w_{Uk}^{\ 1}, w_{Lk}^{\ 1}, w_{U}^{\ 2}, w_{L}^{\ 2}$ are the arbitrary user-chosen non-negative weighting factors.

A typical example of specifications the package can handle directly on return loss and insertion loss for a five-channel multiplexer is shown in Fig. 1. Table 1 gives an example of functions, specifications, weighting factors and frequency bands of interest for optimization.

Basic Variables for Multiplexer Optimization

The following variables must be defined regardless of the mode of optimization selected.

NFREQ is an integer variable, which must be set to the number of frequency points at which the minimax functions are to be created.

OMEGA is a real array of dimension at least NFREQ. It contains arbitrary frequency points (except center frequencies) in MHz at which the minimax functions are to be created.

NFRL is an integer array, which must be set to the number of minimax functions created due to return loss specifications.

Arrays and Codes for Common Port Return Loss Optimization

RLSCODE is an integer array of length at least NFREQ. Each element must be set to the following specification code value at each frequency.

- 0 no specification required,
- -1 only lower specification required,
- 1 only upper specification required,
- both upper and lower specifications required.

SURL is a real array of length at least NFREQ. It must contain the upper specifications applicable at each frequency.

SLRL is a real array of length at least NFREQ. It must contain the lower specifications applicable at each frequency.

WURL is a real array of length at least NFREQ. It must contain the weighting factors corresponding to upper specifications.

WLRL is a real array of length at least NFREQ. It must contain the weighting factors corresponding to lower specifications.

Arrays and Codes for Insertion Loss Optimization

CHBCODE is an integer array of dimensions at least NCH by 2. Each row must contain the range of frequencies over which specifications for the corresponding channel are given. The first element of a row indicates the lower frequency edge of interest, the second the upper frequency edge.

SPCODE is an integer array dimensions at least NSPMAX by NCH. NSPMAX is the maximum number of frequency points considered for any of the channels. Each column must contain the specification code at each frequency for the corresponding channel. Each element of a column must be set to one of the following values:

0 no specification required,

- -1 only lower specifications required,
- only upper specifications required,
- both upper and lower specifications required.

SU is a real array of dimensions at least NSPMAX by NCH. It must contain the upper specifications for each channel ordered consecutively w.r.t. frequency index implied by the CHBCODE matrix in the form (frequency index, channel).

is a real array of dimensions of least NSPMAX by NCH. It must contain the lower specifications for each channel ordered consecutively w.r.t. frequency index implied by the CHBCODE matrix in the form (frequency index, channel).

WU is a real array of dimensions at least NSPMAX by NCH. It must contain the weighting factors for upper specifications. It is arranged to correspond to SU.

WL is a real array of dimensions at least NSPMAX by NCH. It must contain the weighting factors for lower specifications. It is arranged to correspond to SL.

The Starting Point for Optimization

The starting point for optimization must be initialized by setting consecutively numbered X values. It is imperative that the optimization variables for each channel are defined consecutively as follows: variable filter couplings come first, followed by variable input, then output, transformer ratios, the section length being the last variable in the set of optimization variables for a particular channel.

Optimization Entry (Subroutine MMLC1A)

The subroutine call is

CALL MMLC1A (FDF2, NV, MF, L, LEQ, B, C, IIC, X, DX, EPS, MAXF, KEQS, W, IW, ICH, IPR, IFALL).

The arguments are as follows

FDF2	is a name of a subroutine calculating minimax functions and their derivatives $\frac{1}{2}$
	at the point defined by the \boldsymbol{X} vector. The name FDF2 is arbitrary and must
	appear in the EXTERNAL statement in the segment calling MMLC1A.
NV	is an integer argument, which must be set to the number of optimization
	variables. Its value must be positive and is not changed by the package.
MF	is an integer argument, which must be set to the number of residual functions
	defining the minimax objective function. Its value must be positive and is not
	changed by the package.
L	is an integer argument, which must be set to the total number of equality and
	inequality constraints. Its value must be positive or zero and it is not changed
	by the package.
LEQ	is an integer argument, which must be set to the number of equality
	constraints. Its value must be positive or zero and not greater than NV, and
	not greater than L. Its value is not changed by the package.
В	is a real array of length $IIC > L$. The elements of B must be set to the
	constant terms in the linear constraints. The contents of \boldsymbol{B} are not changed by
	the package.
C	is a real matrix of dimensions (IIC, NV). The first L rows of C must be set to
	the coefficients of \mathbf{x} in the linear constraints.
IIC	is an integer argument, which must be set to the length of the array B and to
	the number of rows of the matrix C. Its value must not be less than L, and it is
	not changed by the package.
X	is a real array of length at least NV which, on entry, must be set to the initial
	approximation of the solution. On exit, X contains the best solution found by
	the package.

DX	is a real variable, which controls the step length of the iterative algorithm.
	On entry, it must be set to an initial value approximately equal to $0.1*\ \mathbf{x}^0\ $.
	The value of DX must be positive. On exit, DX contains the last value of the
	stepsize. For extensive details, refer to [1].

EPS is a real variable which, on entry, must be set to the required accuracy of the solution. On exit, EPS contains the length of the last step taken in the iteration.

MAXF is an integer variable which must be set to an upper bound on the number of calls to FDF2. On exit, MAXF contains the number of calls to FDF2 that have been performed by the package.

KEQS is an integer variable, which must be set to the number of successive iterations with identical sets of active residual functions and active constraints that is required before a switch to Stage 2 is made [1]. On exit, KEQS contains the number of switches to Stage 2 that have taken place.

W is a real array which is used for working space. Its length is given by IW. On exit, the first MF elements of W contain the residual function values at the solution.

IW is an integer argument, which must be set to the length of W. The value must be at least

IWR = 2*MF*NV + 5*NV*NV + 4*MF + 8*NV + 4*IIC + 3

ICH is an integer argument, which must be set to the unit number that is to be used for the printed output generated by the package. If ICH is less than or equal to zero, no printed output will be generated by the package.

IPR is an integer argument which controls the printed output generated by the package. For extensive details see [1].

IFALL is an integer variable which on exit contains information about the solution: $IFALL = -2 ext{ feasible region is empty,}$ IFALL = -1 incorrect input data,
IFALL = 0 regular solution, required accuracy obtained,
IFALL = 1 singular solution, required accuracy obtained,
IFALL = 2 machine accuracy reached,
IFALL = 3 maximum number of function evaluations reached,
IFALL = 4 iteration terminated by the user

References

- [1] J.W. Bandler and W.M. Zuberek, "MMLC a Fortran package for linearly constrained minimax optimization", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-5, 1982.
- [2] J.W. Bandler and M.R.M. Rizk, "Optimization of electrical circuits", <u>Mathematical Programming Study II</u>, 1979, pp. 1-64.
- [3] J.W. Bandler, S.H. Chen, S. Daijavad and W. Kellermann, "Optimal design of multicavity filters and contiguous-band multiplexers", <u>Proc. 14th European Microwave Conference</u>, (Liège, Belgium, Sept. 1984).

TABLE 1

EXAMPLE OF FUNCTIONS, SPECIFICATIONS, WEIGHTING FACTORS
AND FREQUENCY BANDS

Function	<u>Specification</u>		Weightin	Weighting Factors		Frequency Band of Interest	
a) insertion loss b) return loss	lower	upper	lower spec.	upper spec.	lower spec.	upper spec.	
a) $F_k^1(\mathbf{x}, \omega_i)$	$S^1_{Lk}(\omega_i)$	$S^{l}_{\ Uk}(\omega_{i})$	$w^1_{Lk}(\omega_i)$	$w^1_{Uk}(\omega_i)$	$[\omega_{ ext{L}k}^{},\omega_{ ext{U}k}^{ ext{L}}]$ and $[\omega_{ ext{L}k}^{ ext{L}},\omega_{ ext{U}k}^{}]$	$[\omega^U_{Lk},\ \omega^U_{Uk}]$	
b) $F^2(\mathbf{x}, \omega_i)$	$S^2_{L}(\omega_i)$	$S^2_U(\omega_i)$	$w_{L}^{2}(\omega_{i})$	$w^2_U(\omega_i)$	[ω ^L _L , ω ^L _U]	$[\omega_{ m L},~\omega^{ m U}_{ m U}]$ and $[\omega^{ m U}_{ m L},~\omega_{ m U}]$	
$egin{aligned} & & & & & & & & & & & & & & & & & & &$	is the channel number is the ith frequency point is the band of interest for the kth channel insertion loss calculations						
$[\omega_L, \omega_U]$	is the band of interest for return loss calculations.						

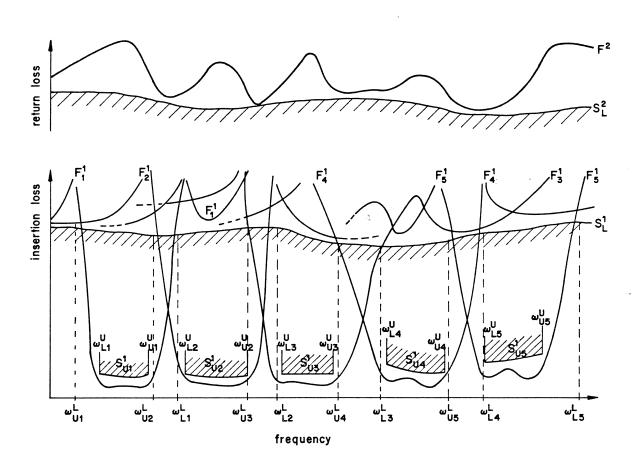


Fig. 1 Five channel example, illustrating our flexibility in choice of responses to be optimized and frequency bands of interest. See the text and Table 1 for some definitions.

MULTIPLEXER OPTIMIZATION: EXAMPLE

Introduction

Suppose we want to design a three-channel, 12 GHz multiplexer without dummy channels such that certain specifications on the common port return loss and individual channel insertion loss functions are satisfied. We start the design process with three identical filters of order six, data for which has been given in the simulation section example.

A lower specification of 20 dB on return loss over the whole band of interest should be satisfied and the following upper specifications on channel insertion loss should also be satisfied for all three channels:

$\omega_0 \pm 10 \mathrm{MHz}$	1.12 dB,
$\omega_0^{}\pm12MHz$	1.24 dB,
$\omega_0^{}\pm14MHz$	1.41 dB,
$\omega_0^{}\pm 16MHz$	1.77 dB,
$\omega_0 \pm 18 \mathrm{MHz}$	2.79 dB.

Fig. 1 shows the shape of specifications for individual channel insertion loss functions and for the common port return loss.

Algorithm for Three Channel, 12 GHz Multiplexer Optimization

Step 1 Select the optimization mode of operation

LMODE = 3.

Step 3 Select the optimization variables and define the corresponding codes to identify them. In this example the multiplexer parameters selected in the

SENSITIVITY EXAMPLE section are declared as optimization variables. This corresponds to executing Steps 3 - 7 from the SENSITIVITY EXAMPLE section.

Select the desired mode of optimization. Since the specifications are defined for the common port return loss and for the individual channel insertion loss functions we select mode of optimization 2.

MODE = 2.

<u>Comment</u> The selected mode of optimization corresponds to the situation in which the minimax functions will be created due to specifications on return loss and insertion loss functions.

Define the starting point for optimization. As indicated earlier in the OPTIMIZATION section, the optimization variables for each channel are defined consecutively as follows: variable filter couplings come first, followed by variable input then output, transformer ratios, the section length being the last variable in the set of optimization variables for a particular channel.

For the optimization problem defined in this section the first fifteen variables (all in channel number 1) are

X(1) = CM(1,1,1)

X(2) = CM(1,1,2)

X(3) = CM(1,2,2)

X(4) = CM(1,2,3)

X95) = CM(1,3,3)

X(6) = CM(1,3,4)

X(7) = CM(1,3,6)

X(8) = CM(1,4,4)

X(9) = CM(1,4,5)

X(10) = CM(1,5,5)

X(11) = CM(1,5,6)

X(12) = CM(1,6,6)

X(13) = PN1(1)

X(14) = PN2(1)

X(15) = WGL(1).

Similarly, the remaining 30 variables (from X(16) to X(45)) should be defined . using parameter values in channels 2 and 3.

Step 6 Select frequency points for optimization. The choice of frequency points at which the minimax functions are to be created is partly dictated by the design specifications. For the problem defined above we select 15 frequency points per channel which are defined as

 $\omega_0 + 0.001 \,\mathrm{MHz}\,,$

 $\omega_0^{} \pm 4 \; MHz$,

 $\omega_0 \pm 8 \, MHz$,

 $\omega_{\rm p} \pm 10~MHz$,

 $\omega_0 \pm 12 \, MHz$,

 $\omega_0 \pm 14 \, MHz$,

 $\omega_0 \pm 16 \, MHz$,

 $\omega_0 \pm 18 \, MHz$.

Those frequency points will be used to create error functions due to insertion loss specifications. At the same frequency points error functions corresponding to return loss specifications will be created. Two additional frequency points for return loss only are selected. These are the two crossover frequencies, namely, 12000.0 MHz and 12040.0 MHz. All frequency points selected in this step are contained in the OMEGA(I) vector.

<u>Step 7</u> Define the total number of frequency points at which the minimax functions are to be created.

NFREQ = 47.

Step 8 Define the number of minimax functions resulting from the specifications on the common port return loss.

$$NFRL = 47$$
.

Step 9 Define the codes and arrays for return loss optimization. To create error functions due to return loss specifications (see the subsection on the formulation of the problem) we have to define the RLSCODE vector indicating the type of specification at each frequency point. In this problem we have only a lower specification of 20 dB on return loss, so the RLSCODE(I) is defined as

$$RLSCODE(I) = [-1 \ -1 ... \ -1]^{T}, I = 1, ..., NFREQ.$$

The SLRL vector contains the actual numerical values of lower specification at each frequency point and is defined as

$$SLRL(I) = [20.0 \ 20.0 \ ... \ 20.0]^{T}, \ I = 1, ..., NFREQ.$$

The WLRL vector containing the weighting factors for lower specification at each free ency point and is defined as

$$WLRL(I) = [1.0 \ 1.0 ... \ 1.0]^T, \ I = 1, ..., NFREQ.$$

<u>Comment</u> The SURL and WURL vectors corresponding to upper specifications need not be defined since no element of the RLSCODE vector is equal to 1 or 2 (indicating only upper or both upper and lower specification).

Step 10 Define the codes and arrays for insertion loss optimization. For each of the multiplexer channels we define a band of frequencies over which specifications for that channel are given using the frequency point indices implied by the vector OMEGA. In this example the channel band code matrix is defined as

CHBCODE(I,J) =
$$\begin{bmatrix} 31 & 45 \\ 16 & 30 \\ 1 & 15 \end{bmatrix}$$
.

The maximum number of frequency points for any of the three channels NSPMAX is 15. This number determines the number of rows in the insertion

loss specification code matrix SPCODE. The number of columns is equal to the number of channels, NCH = 3. In this example only upper specifications for insertion loss functions are given and the SPCODE matrix is

$$SPCODE(I,J) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ . & . & . \\ . & . & . \\ . & . & . \\ 1 & 1 & 1 \end{bmatrix}, I = 1, ..., NSPMAX,$$

According to the SPCODE matrix the actual numerical values of the specifications are given by the SU matrix:

$$SU(1, K) = 2.79$$
,
 $SU(2, K) = 1.77$,
 $SU(3, K) = 1.41$,
 $SU(4, K) = 1.24$,
 $SU(J, K) = 1.12$, $J = 5, 6, ..., 11$, $K = 1, 2, 3$,
 $SU(12, K) = 1.24$,
 $SU(13, K) = 1.41$,
 $SU(14, K) = 1.77$,
 $SU(15, K) = 2.79$.

All weighting factors corresponding to those specifications are assumed to be 1.0, i.e.,

$$WU(J, K) = 1.0$$
 $J = 1, 2, ..., 15, K = 1, 2, 3.$

Comment The SL and WL matrices corresponding to lower specifications need not be defined since no element of the SPCODE matrix is equal to 1 or 2 (only lower or both lower and upper specification).

Step 11 Define arguments for the MMLC1A call statement. The number of optimization variables is

$$NV = 45$$
.

The number of error functions defining the minimax objective function is

$$MF = 92.$$

The total number of equality and inequality constraints is

$$L = 0$$
.

The number of equality constraints is

$$LEQ = 0.$$

The number of constant terms in the linear constraints is

$$IIC = 0.$$

The initial step length of the iterative algorithm is

$$DX = 0.05$$
.

The required accuracy of the solution is

$$EPS = 10^{-6}$$
.

The upper bound on the number of calls of FDF2 is

$$MAXF = 65.$$

The number of successive iterations with identical sets of active functions before a switch to Stage 2 is made

$$KEQS = 3.$$

The overestimate of the length of W (the workspace) is

$$IW = 20000.$$

The unit number for the printed output generated by the package is

$$ICH = 6.$$

The argument which controls the printed output generated by the package is

$$IPR = 10.$$

If IPR is set to 10 variables and function values will be printed out only at the starting point and at the solution.

The listing of the main program implementing the foregoing steps, the corresponding subroutine FDF2 and the results of optimization are shown in Figs. 2-4

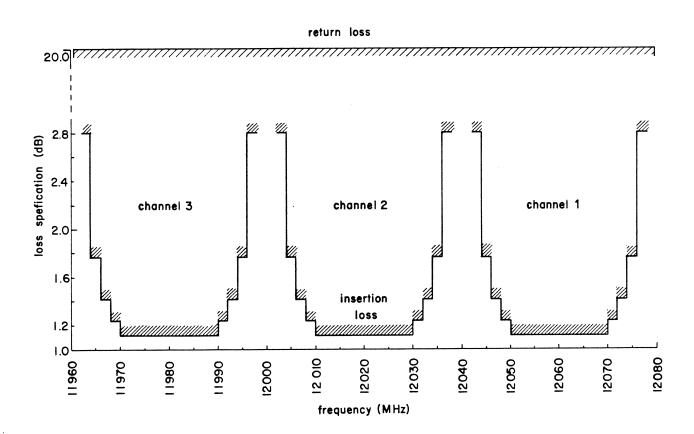


Fig. 1 Illustration of the specifications for the three channel example under consideration.

```
60000000000 000000
```

č

```
000001
PROGRAM MXSOS2(OUTPUT, TAPE6=OUTPUT)
                                                                                                        000000
THIS PROGRAM IS A USER DEFINED MAIN SECMENT OF THE MXSOS2 PACKAGE
                                                                                                        000003
FOR MULTIPLEXER SIMULATION, SENSITIVITY ANALYSIS AND OPTIMIZATION. THE PROGRAM SETS UP ARRAYS, INITIALIZES THE DATA AND EXECUTES SOME
                                                                                                        000004
THE PROGRAM SETS UP ARRAYS,
                                                                                                        000005
THE PROGRAM SETS OF ARRAIS, INTITALIZES THE DATA AND EARLOWS SOME SIMPLE STEPS TO ORGANIZE THE PROBLEM AS REQUIRED BY THE PACKAGE. IT CONSISTS OF THREE PARTS. THE FIRST PART INITIALIZES THE DATA REQUIRED FOR SIMULATION, THE SECOND PART INITIALIZES ADDITIONAL DATA REQUIRED FOR SENSITIVITY ANALYSIS AND THE THIRD PART INITIALIZES THE DATA REQUIRED FOR THE MULTIPLEXER OPTIMIZATION PROBLEM
                                                                                                        000006
                                                                                                        000007
                                                                                                        000008
                                                                                                        000009
                                                                                                        000010
OF INTEREST INCLUDING SPECIFICATIONS AND WEIGHTING FACTORS AS WELL AS THE DATA REQUIRED BY THE MINIMAX OPTIMIZATION PACKAGE MMLC. AT
                                                                                                        000011
                                                                                                        000012
THIS TIME ONLY COMMON PORT RETURN LOSS AND CHANNEL INSERTION LOSS IN DB ARE HANDLED FOR OPTIMIZATION. IN THE CASE OF SIMULATION
                                                                                                        000013
                                                                                                        000014
GROUP DELAY IS ESTIMATED BY DIFFERENCING THE PHASE AT A PAIR
                                                                                                        000015
OF FREQUENCIES.
                                                                                                        000016
                                                                                                        000017
THE USER MUST PROVIDE APPROPRIATE DIMENSIONS FOR THE FOLLOWING VARIABLES AFTER STUDYING THE COMMENTS PLACED THROUGHOUT THE MAIN SEGMENT MXSOS2. CORRESPONDING DIMENSIONS MUST BE DECLARED IN ALL
                                                                                                        000018
                                                                                                        000019
                                                                                                        000020
SUBROUTINES EXCEPT FOR THE MMLC PACKAGE.
                                                                                                        000021
                                                                                                        000022
REAL X(45), W(20000), B(1), C(1,1), T(3), DISP(16), QO(16) REAL OMEGA(47), SURL(47), SLRL(47), WURL(47), WLRL(47),
                                                                                                        000023
                                                                                                        000024
SU(20,16), SL(20,16), WU(20,16), WL(20,16)
INTEGER RLSCODE(47), SPCODE(20,16), CHBCODE(16,2)
REAL WO(16), BW(16), CM(16,8,8), PN1(16), PN2(16), SPN1(16), SPN2(16),
                                                                                                        000025
                                                                                                        000026
                                                                                                        000027
             CL(16), WCL(16), DIA(16)
                                                                                                        000028
INTEGER CEL(16,8,8)
                                                                                                        000029
REAL FCNST(16), LAMRES(16), LAMDEL(16)
                                                                                                        000030
                                                                                                        000031
REAL DRL(100), FIL(16), DIL(16, 100)
REAL ANGLE1(16), ANGLE2(16), GRDEL(16)
INTEGER IR(16), IRT(16), IPN1(16), IPN2(16), IWG(16)
                                                                                                        000032
                                                                                                        000033
                                                                                                        000034
INTEGER LC(16,36), KC(16,36)
EXTERNAL FDF2
                                                                                                        000035
COMMON /BLK1/WO, BW, PN1, PN2, GL, VS, RS, P12, WIDTH, NP1
                                                                                                        000036
COMMON /BLK2/CM, WGL
                                                                                                        000037
COMMON /BLK3/OMEGA, SURL, SLRL, WURL, WLRL, SU, SL, WU, WL, RLSCODE, SPCODE, NCOUNT, MODE, NCH, MO, NFREQ, NFRL,
                                                                                                        000038
                                                                                                        000039
          CHBCODE, IFLAGJS, IFLAGDP, IDISPER
                                                                                                        000040
COMMON /BLK4/CBR, FCUT
                                                                                                        000041
COMMON /BLK5/DISP
                                                                                                        000042
COMMON/BLK6/FCNST, LAMRES, LAMDEL
                                                                                                        000043
COMMON/BLK7/CEL
                                                                                                        000044
COMMON/BLK8/IR, IRT, IPN1, IPN2, IWG, LC, KC
                                                                                                        000045
DATA T/10HMULTIPLEXE, 10HR PROBLEM , 10HMXTST6C
                                                                                                        000046
                                                                                                        000047
THE MXSOS2 PACKAGE CAN OPERATE IN THREE MODES: SIMULATION,
                                                                                                        000048
VITY ANALYSIS AND OPTIMIZATION. TO SELECT THE REQUIRED FUNCTION OF
                                                                                                        000049
THE PACKAGE SET LMODE TO

1 - IF MULTIPLEXER SIMULATION IS REQUIRED,

2 - IF MULTIPLEXER SENSITIVITY ANALYSIS IS REQUIRED,
                                                                                                        000050
                                                                                                        000051
                                                                                                        000052
3 - IF MULTIPLEXER OPTIMIZATION IS REQUIRED.
                                                                                                        000053
                                                                                                        000054
SELECT MODE OF OPERATION OF THE PACKAGE
                                                                                                        000055
                                                                                                        000056
LMODE=3
                                                                                                        000057
                                                                                                        000058
THIS PART OF THE MAIN SECMENT IS USED TO DEFINE THE DATA FOR
                                                                                                        000059
MULTIPLEXER SIMULATION. IT MUST ALWAYS BE DEFINED, REGARDLESS OF THE MODE OF OPERATION OF THE PACKAGE SELECTED.
                                                                                                        000060
                                                                                                        000061
                                                                                                        000062
             NUMBER OF FILTER CHANNELS INCLUDING DUMMY CHANNELS
                                                                                                        000063
NCII
          - ORDER OF FILTERS(THE SAME FOR ALL FILTERS, ODD OR EVEN)
                                                                                                        000064
MO
WO
          - VECTOR OF CENTER FREQUENCIES IN MHZ, ONE PER CHANNEL
                                                                                                        000065
```

Fig. 2 Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000066
                - VECTOR OF UNLOADED Q FOR THE FILTERS, ONE PER CHANNEL
C
       \mathbf{Q}\mathbf{0}
                  VECTOR OF FILTER DIAMETERS IN INCHES, ONE PER CHANNEL VECTOR OF CHANNEL BANDWIDTHS IN MHZ, ONE PER CHANNEL
                                                                                             000067
C
       DIA
                                                                                             000068
       RW
                - VECTOR OF INPUT TRANSFORMER RATIOS(SQUARED), ONE PER
                                                                                             000069
       SPN1
                                                                                             000070
\mathbf{C}
                   CHANNEL
                                                                                             000071
Ċ
       SPN2
                  VECTOR OF OUTPUT TRANSFORMER RATIOS(SQUARED), ONE PER
Ċ
                                                                                             000072
                   CHANNEL
                  VECTOR OF CHANNEL TERMINATING CONDUCTANCES, ONE PER
                                                                                             000073
C
       CI.
                                                                                             000074
                   CHANNEL
                  SYMMETRICAL MATRIX OF COUPLING PARAMETERS (CHANNEL, ROW,
                                                                                             000075
\mathbf{c}
       CM
                                                                                             000076
                   COLUMN), INCLUDING NONZERO DIAGONAL ELEMENTS TO MODEL
CCC
                   ASYNCHRONOUS DESIGNS
                                                                                             000077
                                                                                             000078
                - SYMMETRICAL MATRIX FOR TYPE OF COUPLING,
                                                                      +1 FOR SCREW,
       CEL
                 -1 FOR IRIS, CORRESPONDING TO CM AS ABOVE
VECTOR OF WAVEGUIDE SPACINGS FOR EACH CHANNEL, MEASURED
IN INCHES ALONG THE MANIFOLD FROM THE ADJACENT CHANNEL
(DISTANCE FROM THE SHORT CIRCUIT FOR THE FIRST CHANNEL)
SOURCE VOLTAGE AT THE COMMON PORT
                                                                                             000079
                                                                                             000080
       WGL
                                                                                             000081
Č
                                                                                             000082
       VS
                                                                                             000083
                - SOURCE RESISTANCE AT THE COMMON PORT
- CONSTANT EQUAL TO TWICE PI
                                                                                             000084
\mathbf{c}
       RS
                                                                                             000085
       P12
                                                                                             000086
C
       WIDTH
                - MANIFOLD WIDTH IN INCHES
                                                                                             000087
                                                                                             000088
       DEFINE THE NUMBER OF CHANNELS AND THE ORDER OF THE FILTERS
\mathbf{c}
                                                                                             000089
                                                                                             000090
                                                                                             000091
       MO=6
       NP 1 = NCH+ 1
                                                                                             000092
                                                                                             000093
                                                                                             000094
       DEFINE CENTER FREQUENCIES IN MHZ
                                                                                             000095
\mathbf{C}
                                                                                             000096
       WO(1) = 12060.0
                                                                                             000097
       WO(2) = 12020.0
                                                                                             000098
       WO(3) = 11980.0
                                                                                             000099
                                                                                             000100
       DEFINE UNLOADED Q FACTORS OF THE FILTERS
                                                                                             000101
C
                                                                                             000102
       DO 5 I=1, NCH
                                                                                             000103
       QO(I) = 12000.0
                                                                                             000104
    5 CONTINUE
                                                                                             000105
       DEFINE THE DIAMETER OF THE FILTERS IN INCHES
                                                                                             000106
C
                                                                                             000107
                                                                                             000108
       DO 70 I=1, NCH
                                                                                             000109
       DIA(I) = 1.07
                                                                                             000110
   70 CONTINUE
                                                                                             000111
       DEFINE BANDWIDTHS, INPUT/OUTPUT TRANSFORMER RATIOS AND OUTPUT
                                                                                             000112
                                                                                             000113
C
       CONDUCTANCES
                                                                                             000114
                                                                                             000115
       DO 1 I=1, NCH
                                                                                             000116
       BW(1) = 39.5
       GL(I) = 1.0
                                                                                             000117
                                                                                             000118
       SPN1(1)=0.69967
                                                                                             000119
       SPN2(I) = 1.09450
                                                                                             000120
       PN1(1)=SQRT(SPN1(1))
                                                                                             000121
       PN2(I)=SQRT(SPN2(I))
     1 CONTINUE
                                                                                             000122
                                                                                             000123
C
       DEFINE THE SYMMETRICAL COUPLING MATRIX. ONLY THE UPPER PART OF THE
                                                                                             000124
                                                                                             000125
       CM MATRIX HAS TO BE DEFINED.
                                                                                             000126
                                                                                             000127
       DO 30 I=1, NCH
                                                                                             000128
       DO 30 J=1, MO
                                                                                             000129
       DO 30 KK=1, MO
                                                                                             000130
       CM(I, J, KK) = 0.0
```

Fig. 2 (continued)

Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000131
   30 CONTINUE
      DO 2 I=1,NCH
CM(I,1,2)=0.59395
                                                                                    000132
                                                                                    000133
                                                                                    000134
      CM(1,2,3) = 0.53514
                                                                                    000135
       CM(I,3,4) = 0.42471
                                                                                    000136
      CM(1,3,6) = -0.39967
      CM(1,4,5) = 0.83371

CM(1,5,6) = 0.76313
                                                                                    000137
                                                                                    000138
                                                                                    000139
    2 CONTINUE
                                                                                    000140
0000
                                                                                    000141
      DEFINE THE TYPE OF COUPLING IN THE FILTER
                +1 >> SCREW COUPLING
                                         -1 >> IRIS COUPLING
                                                                                    000142
                                                                                    000143
                                                                                    000144
      DO 71 I=1, NCH
                                                                                    000145
      DO 71 J=1, MO
                                                                                    000146
       DO 71 KK=1, MO
                                                                                    000147
       CEL(I,J,KK) = 0
                                                                                    000148
   71 CONTINUE
                                                                                    000149
C
                                                                                    000150
       DO 72 I=1, NCH
                                                                                    000151
       CEL(I,1,2)=1
                                                                                    000152
       CEL(1,2,3) = -1
                                                                                    000153
       CEL(1,3,4)=1
                                                                                    000154
       CEL(1,3,6) = -1
       CEL(1,4,5) = -1
                                                                                    000155
                                                                                    000156
       CEL(1,5,6)=1
                                                                                    000157
\mathbf{C}
                                                                                    000158
       DO 72 J=1, MO
                                                                                    000159
       DO 72 KK=1,J
                                                                                    000160
       CEL(I,J,KK) = CEL(I,KK,J)
                                                                                    000161
   72 CONTINUE
                                                                                    000162
       DEFINE THE SECTION LENGTHS (SPACINGS ALONG THE WAVEGUIDE MANIFOLD)
                                                                                    000163
\mathbf{c}
                                                                                    000164
                                                                                    000165
       WGL(1) = 0.641
                                                                                    000166
       WGL(2) = 0.631
                                                                                    000167
       WCL(3) = 0.633
                                                                                    000168
       DEFINE SOME CONSTANTS, SOURCE VOLTAGE, SOURCE RESISTANCE, TWICE PI
                                                                                    000169
C
      MANIFOLD WIDTH
                                                                                    000170
                                                                                    000171
C
                                                                                    000172
       VS=1.0
                                                                                    000173
       RS=1.0
                                                                                    000174
       P12=8.0*ATAN(1.0)
                                                                                    000175
       WIDTH=0.75
                                                                                    000176
       THE MXSOS2 PACKAGE CAN EXPLOIT THREE PRACTICAL MODELS OF THE
                                                                                    000177
                                                                                    000178
       MULTIPLEXER AS DETERMINED BY THE PARAMETERS IFLAGJS, IFLAGDP
                                                                                    000179
0000
       AND IDISPER.
                                                                                    000180
                                                                                    000181
       IFLAGJS
       0 - IF JUNCTIONS ARE IDEAL
                                                                                    000182
                                                                                    000183
       1 - IF JUNCTIONS ARE NONIDEAL
00000000000
                                                                                    000184
                                                                                    000185
       IFLAGDP
       0 - IF FILTERS ARE LOSSLESS
1 - IF FILTERS ARE LOSSY
                                                                                    000186
                                                                                    000187
                                                                                    000188
                                                                                    000189
                                                                                    000190
       0 - IF FILTERS ARE DISPERSIVE
                                                                                    000191
       1 - IF FILTERS ARE NONDISPERSIVE
                                                                                    000192
       FLAG FOR JUNCTION SUSCEPTANCE (SET TO 0 OR 1)
                                                                                    000193
                                                                                    000194
                                                                                    000195
       IFLAGJS=1
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000196
        IF (IFLAGJS.NE.1) GO TO 42
                                                                                                        000197
\mathbf{C}
                                                                                                        666198
        CALL CONSTICUIDTH)
                                                                                                        000199
\mathbf{C}
                                                                                                        000200
    42 CONTINUE
                                                                                                        666261
        FLAG FOR FILTER DISSIPATION (SET TO 0 OR 1)
C
                                                                                                        000202
                                                                                                        666263
\tilde{\mathbf{C}}
                                                                                                        000204
        IFLAGDP=1
        IF(IFLACDP.NE.1)GO TO 43
                                                                                                        000205
                                                                                                        000206
C
                                                                                                        000207
        CALL DISPAT(NCH, WO, BW, QO)
                                                                                                        000208
C
                                                                                                        000209
    43 CONTINUE
                                                                                                        000210
\mathbf{C}
        FLAG FOR DISPERSIVE EFFECTS IN THE COUPLED CAVITY FILTERS
                                                                                                        000211
C
                                                                                                        000212
        (SET TO 0 OR 1)
                                                                                                        000213
\mathbf{C}
         IDISPER= 1
                                                                                                        000214
        IF(IDISPER.NE.1)GO TO 44
                                                                                                        000215
                                                                                                        000216
\mathbf{C}
                                                                                                        000217
        CALL DISPER(NCH, WO, BW, DIA)
                                                                                                        000218
C
                                                                                                        666219
    44 CONTINUE
                                                                                                        000220
\mathbf{C}
        CHECK WHETHER THE SIMULATION MODE IS REQUIRED
                                                                                                        000221
                                                                                                        000222
\mathbf{C}
                                                                                                        000223
        IF(LMODE.NE.1)GO TO 16
C
                                                                                                        000224
        SENSITIVITY ANALYSIS, CORRESPONDING TO LMODE=2
                                                                                                        000225
                                                                                                        000226
0000000000000000000000000000
        THIS PART OF THE MAIN PROGRAM IS USED TO DEFINE CODES FOR MULTI-
PLEXER PARAMETERS W.R.T. WHICH WE WANT TO FIND THE SENSITIVITIES.
                                                                                                        000227
                                                                                                        000228
        THE PARAMETER IR(I)=0 SIGNIFIES THAT NO ELEMENTS OF THE FILTER COUPLING MATRICES ARE OPTIMIZATION VARIABLES. SUBROUTINE
                                                                                                        000229
                                                                                                        000230
         "SIMGRD2" IS CALLED AT EACH FREQUENCY DEFINED IN THE VECTOR
                                                                                                        000231
                                                                                                        000232
        OMEGA(1).
                                                                                                        000233
                  - VECTOR CONTAINING THE NUMBER OF COUPLING PARAMETERS BE-
                                                                                                        000234
        IR
                     ING VARIABLES FOR EACH CHANNEL
                                                                                                        000235
                    MATRIX CONTAINING THE ROW INDICES OF COUPLING PARAMETERS BEING VARIABLES FOR EACH CHANNEL
                                                                                                        000236
        LC
                                                                                                        000237
                  - MATRIX CONTAINING THE COLUMN INDICES OF COUPLING PARAME-
                                                                                                        000238
        KC
                    TERS BEING VARIABLES FOR EACH CHANNEL
INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING
WHETHER THE INPUT TRANSFORMER RATIO IS AN OPTIMIZATION
VARIABLE (IPN1(1)=1) OR NOT (IPN1(1)=0).
                                                                                                        000239
                                                                                                        000240
        IPNI
                                                                                                        000241
                                                                                                        000242
                  - INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING WHETHER THE OUTPUT TRANSFORMER RATIO IS AN OPTIMIZATION VARIABLE (IPN2(I)=1) OR NOT (IPN2(I)=0).
                                                                                                        000243
        IPN2
                                                                                                        000244
                                                                                                        000245
                    INTEGER ARRAY OF DIMENSION AT LEAST NCH INDICATING WHETHER THE WAVEGUIDE SECTION LENGTH IS AN OPTIMIZATION VARIABLE (IWG(1)=1) OR NOT (IWG(1)=0).

VECTOR OF ARBITRARY FREQUENCIES (EXCEPT CENTER FREQUENCIES)
                                                                                                        000246
        ING
                                                                                                        000247
                                                                                                        000248
                                                                                                        000249
        OMECA
                     CIES) AT WHICH THE SENSITIVITY ANALYSIS IS TO BE PERFOR-
                                                                                                        000250
                                                                                                        000251
                    ACTUAL FREQUENCY AT WHICH THE SUBROUTINE "SIMGRD" IS
                                                                                                        000252
        FRSNS
                                                                                                        000253
CCCCC
                     CALLED
                     TOTAL NUMBER OF VARIABLES W.R.T. WHICH THE SENSITIVITIES
                                                                                                        000254
        NV
                     ARE REQUIRED
                                                                                                        000255
                     VALUE OF THE COMMON PORT RETURN LOSS IN DB AT THE FREQU-
                                                                                                        000256
        FRL
                                                                                                        000257
                     ENCY FRSNS
                    SENSITIVITIES OF THE COMMON PORT RETURN LOSS W.R.T. ALL
C
        DRL
                                                                                                        000258
                                                                                                        000259
C
                     VARIABLES
        FIL
                  - VECTOR OF THE INSERTION LOSS FUNCTION IN DB FOR EACH
                                                                                                        000260
```

Fig. 2 (continued)

Listing of MXSOS2 and the subroutine $F \acute{DF}2$ arranged for optimization.

```
CHANNEL AT THE FREQUENCY FRSNS
                                                                                          000261
CCC
                 MATRIX OF SENSITIVITIES OF THE INSERTION LOSS FUNCTION FOR EACH CHANNEL W.R.T. ALL VARIABLES
       DIL
                                                                                          000262
                                                                                          000263
                                                                                          000264
C
       DEFINE THE NUMBER OF COUPLING VARIABLES PER CHANNEL
                                                                                          000265
\mathbf{C}
                                                                                          000266
                                                                                          000267
   16 CONTINUE
                                                                                          000268
       IR(1) = 12
       IR(2) = 12
                                                                                          000269
                                                                                          000270
       1R(3) = 12
                                                                                          000271
       DEFINE CODES TO IDENTIFY VARIABLES FOR INPUT-OUTPUT TRANSFORMER
C
                                                                                          000272
č
       RATIOS AND WAVEGUIDE SPACINGS
                                                                                          000273
                                                                                          000274
                                                                                          000275
       DO 55 I=1,NCH
                                                                                          000276
       IWG(1) = 1
                                                                                          000277
       IPN1(I)=1
       IPN2(I)=1
                                                                                          000278
   55 CONTINUE
                                                                                          000279
                                                                                          000280
\mathbf{c}
       EVALUATE THE TOTAL NUMBER OF VARIABLES ACCUMULATED AFTER
                                                                                          000281
\mathbf{c}
                                                                                          000282
\mathbf{C}
       EACH SECTION
C
                                                                                          000283
       CALL TOTAL2(NCH, IR, IRT, IPN1, IPN2, IWG)
                                                                                          000284
                                                                                          000285
C
       DEFINE CODES FOR THE VARIABLES CONTAINED IN THE COUPLING MATRICES
                                                                                          000286
\mathbf{c}
                                                                                          000287
\mathbf{c}
       DO 127 I=1,3
                                                                                          000288
      LC(I,1)=1
LC(I,2)=1
                                                                                          000289
                                                                                          000290
       LC(1,3)=2
                                                                                          000291
                                                                                          000292
       LC(I,4)=2
                                                                                          000293
       LC(1,5)=3
       LC(1,6)=3
LC(1,7)=3
                                                                                          000294
                                                                                          000295
                                                                                          000296
       LC(1,8)=4
                                                                                          000297
       LC(1,9)=4
                                                                                          000298
       LC(I, 10) = 5
                                                                                          000299
       LC(1,11)=5
                                                                                          000300
       LC(1, 12) = 6
       KC(I,1)=1
KC(I,2)=2
                                                                                          000301
                                                                                          000302
                                                                                          000303
       KC(1,3)=2
       KC(1,4)=3
                                                                                          000304
       KC(1,5)=3
                                                                                          000305
       KC(1,6)=4
KC(1,7)=6
                                                                                          000306
                                                                                          000307
                                                                                          000308
       KC(1,8)=4
                                                                                          000309
       KC(1,9)=5
       KC(1, 10) = 5
                                                                                          000310
                                                                                          000311
       KC(I, 11) = 6
                                                                                          000312
       KC(1, 12) = 6
                                                                                          000313
  127 CONTINUE
                                                                                          000314
C
C
       CHECK WHETHER THE SIMULATION AND SENSITIVITY ANALYSIS MODE
                                                                                          000315
Č
       IS REQUIRED
                                                                                          000316
                                                                                          000317
                                                                                          000318
       IF(LMODE.NE.2) CO TO 17
C
                                                                                          000319
C
       OPTIMIZATION, CORRESPONDING TO LMODE=3
                                                                                          000320
C
                                                                                          000321
       THIS PART OF THE MAIN SEGMENT IS USED TO DEFINE ALL VARIABLES AND
                                                                                          000322
\mathbf{c}
       ARRAYS FOR MULTIPLEXER OPTIMIZATION. TO SELECT THE MULTIPLEXER PARAMETERS WHICH ARE THE OPTIMIZATION VARIABLES THE MATRICES LC AND
                                                                                          000323
C
                                                                                          000324
                                                                                          000325
       KC HAVE TO BE USED AS DESCRIBED IN THE SENSITIVITY ANALYSIS PART.
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000326
          THREE MODES OF OPTIMIZATION ARE ALLOWED. TO SELECT THE DESIRED
C
                                                                                                                               000327
          MODE OF OPTIMIZATION SET PARAMETER MODE TO
          0 - IF ONLY COMMON PORT RETURN LOSS OPTIMIZATION IS REQUIRED 1 - IF ONLY INSERTION LOSS OPTIMIZATION IS REQUIRED
                                                                                                                               000328
                                                                                                                               000329
          2 - IF BOTH RETURN LOSS AND INSERTION LOSS OPTIMIZATION ARE
                                                                                                                               000330
                                                                                                                               000331
                 REQUIRED.
         IN EACH CASE A DIFFERENT HEADER FOR THE PRINTOUT OF OPTIMIZATION RESULTS CAN BE OBTAINED BY CALLING THE SUBROUTINE "MMXHDR" FOR WHICH THE ARGUMENT T CAN BE DEFINED USING THE DATA STATEMENT. VALUES OF OPTIMIZATION VARIABLES AT THE STARTING POINT MUST BE SUPPLIED BY DEFINING THE X VECTOR USING EITHER THE DATA STATEMENT OR EXPLICITLY. THE MINIMAX FUNCTIONS ARE CREATED AT THE FREQUENCIES DEFINED IN THE VECTOR OMEGA(I), WHICH IS A REAL ARRAY OF LENGTH
                                                                                                                               000332
                                                                                                                               000333
                                                                                                                               000334
                                                                                                                               000335
                                                                                                                               000336
                                                                                                                               000337
                                                                                                                               000338
                                                                                                                               000339
          AT LEAST NFREQ.
\mathbf{C}
                                                                                                                               000340
          NFREQ - NUMBER OF FREQUENCY POINTS AT WILCH THE MINIMAX FUNCTI-
                                                                                                                               000341
\mathbf{c}
                                                                                                                               000342
                         ONS ARE TO BE CREATED
                         VECTOR OF ARBITRARY FREQUENCY POINTS (EXCEPT CENTER FREQUENCIES) IN MHZ AT WHICH THE MINIMAX FUNCTIONS ARE TO
                                                                                                                               000343
          OMEGA
C
                                                                                                                               000344
\mathbf{C}
                                                                                                                               000345
                         BE CREATED
C
                      - NUMBER OF MINIMAX FUNCTIONS CREATED DUE TO RETURN LOSS
                                                                                                                               000346
          NFRL
                                                                                                                               000347
                          SPECIFICATIONS
                                                                                                                               000348
                                                                                                                               000349
          ARRAYS AND CODES FOR COMMON PORT RETURN LOSS OPTIMIZATION
                                                                                                                               000350
         RLSCODE- INTEGER ARRAY OF LENGTH AT LEAST NFREQ. EACH ELEMENT MUST BE SET TO THE FOLLOWING SPECIFICATION CODE VALUE AT EACH
                                                                                                                               000351
C
                                                                                                                               000352
                                                                                                                               000353
                         FREQUENCY:
                                                                                                                               000354
                          0 - NO SPECIFICATION REQUIRED
Ċ
                        -1 - ONLY LOWER SPECIFICATION REQUIRED
1 - ONLY UPPER SPECIFICATION REQUIRED
Č
                                                                                                                               000355
                                                                                                                               000356
                        2 - BOTH UPPER AND LOWER SPECIFICATIONS REQUIRED REAL ARRAY OF LENGTH AT LEAST NFREQ. IT MUST CONTAIN THE
                                                                                                                               000357
\mathbf{C}
                                                                                                                               000358
          SUIL
                        UPPER SPECIFICATIONS APPLICABLE AT EACH FREQUENCY REAL ARRAY OF LENGTH AT LEAST NFREQ. IT MUST CONTAIN THE LOWER SPECIFICATIONS APPLICABLE AT EACH FREQUENCY
                                                                                                                               000359
Ċ
                                                                                                                               000360
          SLIL
                                                                                                                               000361
C
                      - REAL ARRIAY OF LENGTH AT LEAST NFREQ. IT MUST CONTAIN THE WEIGHTING FACTORS CORRESPONDING TO UPPER SPECIFICATIONS
                                                                                                                               000362
          WURL
                                                                                                                               000363
                      - REAL ARRAY OF LENGTH AT LEAST NFREQ. IT MUST CONTAIN THE
                                                                                                                               000364
C
          WLRL
                          WEIGHTING FACTORS CORRESPONDING TO LOWER SPECIFICATIONS
                                                                                                                               000365
Ċ
                                                                                                                               000366
          ARRAYS AND CODES FOR INSERTION LOSS OPTIMIZATION
                                                                                                                               000367
                                                                                                                               000368
                                                                                                                               000369
          CHBCODE- INTEGER ARRAY OF DIMENSIONS AT LEAST NCH BY 2. EACH ROW
C
                         MUST CONTAIN THE RANGE OF FREQUENCIES OVER WHICH SPECI-
FICATIONS FOR THE CORRESPONDING CHANNEL ARE GIVEN. THE
                                                                                                                               000370
\mathbf{C}
                                                                                                                               000371
         FIGATIONS FOR THE CORRESPONDING CHANNEL ARE CIVEN. THE FIRST ELEMENT OF A ROW INDICATES THE LOWER FREQUENCY EDGE OF INTEREST, THE SECOND THE UPPER FREQUENCY EDGE.

SPCODE - INTEGER ARRAY OF DIMENSIONS AT LEAST NSPMAX BY NCH.

NSPMAX IS THE MAXIMUM NUMBER OF FREQUENCY POINTS CONSIDERED FOR ANY OF THE CHANNELS.
                                                                                                                               000372
                                                                                                                               000373
                                                                                                                               000374
                                                                                                                               000375
                                                                                                                               000376
                         FACH COLUMN MUST CONTAIN THE SPECIFICATION CODE AT EACH FREQUENCY FOR THE CORRESPONDING CHANNEL. EACH ELEMENT OF A COLUMN MUST BE SET TO ONE OF THE FOLLOWING VALUES:
                                                                                                                               000377
                                                                                                                               000378
C
                                                                                                                               666379
CCC
                         0 - NO SPECIFICATION REQUIRED
                                                                                                                               000380
                       -1 - ONLY LOWER SPECIFICATION REQUIRED
1 - ONLY UPPER SPECIFICATION REQUIRED
2 - BOTH UPPER AND LOWER SPECIFICATIONS REQUIRED
                                                                                                                               000381
                                                                                                                               000382
                                                                                                                               000383
                      - REAL ARRAY OF DIMENSIONS AT LEAST NSPMAX BY NCH. IT MUST CONTAIN THE UPPER SPECIFICATIONS FOR EACH CHANNEL ORDERED CONSECUTIVELY W.R.T. FREQUENCY INDEX IMPLIED
                                                                                                                               000384
          SU
                                                                                                                               000385
                                                                                                                               000386
                         BY THE CHBCODE MATRIX IN THE FORM (FREQUENCY INDEX,
                                                                                                                               000387
                                                                                                                               000388
                          CHANNEL)
                         REAL ARRAY OF DIMENSIONS AT LEAST NSPMAX BY NCH. IT
                                                                                                                               000389
          SL
                          MUST CONTAIN THE LOWER SPECIFICATIONS FOR EACH CHANNEL
                                                                                                                               000390
```

Fig. 2 (continued)

Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000391
                     ORDERED CONSECUTIVELY W.R.T. FREQUENCY INDEX IMPLIED
\mathbf{C}
                     BY THE CHBCODE MATRIX IN THE FORM (FREQUENCY INDEX,
                                                                                                        000392
0000
                                                                                                         000393
                     CHANNEL).
                  CHANNELY.

REAL ARRAY OF DIMENSIONS AT LEAST NSPMAX BY NCH. IT MUST CONTAIN THE WEIGHTING FACTORS FOR UPPER SPECIFICATIONS. IT IS ARRANGED TO CORRESPOND TO SU.

REAL ARRAY OF DIMENSIONS AT LEAST NSPMAX BY NCH. IT MUST CONTAIN THE WEIGHTING FACTORS FOR LOWER SPECIFICATIONS. IT IS ARRANGED TO CORRESPOND TO SL.
        WU
                                                                                                         000394
                                                                                                         000395
C
                                                                                                        000396
                                                                                                        000397
        WL
                                                                                                        000398
0000
                                                                                                         000399
                                                                                                         000400
                                                                                                        000401
                                                                                                        000402
    17 CALL MMXHDR(3,T)
                                                                                                        000403
\mathbf{C}
\overline{\mathbf{C}}
        SELECT THE DESIRED MODE OF OPTIMIZATION
                                                                                                        000404
                                                                                                        000405
                                                                                                         000406
        MODE=2
                                                                                                         000407
000000000
        THE STARTING POINT FOR OPTIMIZATION MUST BE INITIALIZED BY
                                                                                                        000408
        SETTING CONSECUTIVELY NUMBERED X VALUES. IT IS IMPERATIVE THAT THE OPTIMIZATION VARIABLES FOR EACH CHANNEL ARE DEFINED CON-
                                                                                                        000409
                                                                                                         000410
        SECUTIVELY AS FOLLOWS: VARIABLE FILTER COUPLINGS COME FIRST,
                                                                                                         000411
        FOLLOWED BY VARIABLE INPUT, THEN OUTPUT, TRANSFORMER RATIOS, THE SECTION LENGTH BEING THE LAST VARIABLE IN THE SET OF OPTI-
                                                                                                         000412
                                                                                                        000413
                                                                                                        000414
        MIZATION VARIABLES FOR A PARTICULAR CHANNEL.
                                                                                                        000415
                                                                                                         000416
        X(1) = CM(1,1,1)
                                                                                                        000417
        X(2) = CM(1,1,2)
                                                                                                        000418
        X(3) = CM(1,2,2)
                                                                                                         000419
        X(4) = CM(1,2,3)
                                                                                                        000420
        X(5) = CM(1,3,3)
        X(6) = CM(1,3,4)
                                                                                                        000421
        X(7) = CM(1,3,6)
                                                                                                        000422
                                                                                                         000423
        X(8) = CM(1,4,4)
        X(9) = CM(1,4,5)

X(10) = CM(1,5,5)
                                                                                                        000424
                                                                                                        000425
                                                                                                        000426
        X(11) = CM(1,5,6)
        X(12) = CM(1,6,6)
                                                                                                        000427
        X(13) = PNI(1)
                                                                                                        000428
        X(14)=PN2(1)
X(15)=WGL(1)
                                                                                                         000429
                                                                                                        000430
                                                                                                        000431
         X(30) = WGL(2)
                                                                                                        000432
         X(45) = WGL(3)
         DO 128 I=1,14
                                                                                                        000433
         I I = I + 15
                                                                                                        000434
        X(II) = X(I)
                                                                                                         000435
                                                                                                        000436
         I I I = I+30
                                                                                                         000437
         X(III) = X(I)
   128 CONTINUE
                                                                                                        000438
                                                                                                        000439
C
         GENERATE FREQUENCY POINTS IN MHZ
                                                                                                         000440
                                                                                                         000441
                                                                                                         000442
        NFREQ=47
                                                                                                         000443
        OMEGA(1) = 11962.0
         OMEGA(2) = 11964.0
                                                                                                        000444
        OMEGA(3) = 11966.0
                                                                                                         000445
                                                                                                         000446
         OMEGA(4) = 11968.0
                                                                                                         000447
         OMEGA(5) = 11970.0
                                                                                                        000448
         OMEGA(6) = 11972.0
                                                                                                        000449
         OMEGA(7) = 11976.0
                                                                                                        000450
         OMEGA(8) = 11980.0001
         OMEGA(9) = 11984.0
                                                                                                         000451
         OMEGA(10) = 11988.0
                                                                                                         000452
                                                                                                         000453
         OMEGA(11)=11990.0
                                                                                                         000454
         OMEGA(12) = 11992.0
         OMEGA(13)=11994.0
                                                                                                         000455
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000456
        OMEGA(14)=11996.0
                                                                                                     000457
        OMEGA(15) = 11998.0
                                                                                                     000458
        DO 10 1=16,45
        OMEGA(I) = OMEGA(I-15)+40.0
                                                                                                      000459
                                                                                                      000460
    10 CONTINUE
                                                                                                     000461
        OMEGA(46) = 12000.0
                                                                                                     666462
        OMEGA(47) = 12040.0
                                                                                                     000463
        DEFINE THE NUMBER OF MINIMAX FUNCTIONS RESULTING FROM THE
                                                                                                      000464
\mathbf{c}
        SPECIFICATIONS ON RETURN LOSS
                                                                                                     000465
                                                                                                     000466
\mathbf{C}
                                                                                                     000467
                                                                                                     000468
\mathbf{C}
        DEFINE CODES AND ARRAYS REQUIRED FOR RETURN LOSS OPTIMIZATION
                                                                                                     000469
                                                                                                     000470
                                                                                                     000471
        DO 150 I=1,47
        RLSCODE(I) = -1
                                                                                                     000472
                                                                                                     000473
        SLRL(1) = 20.0
        WLRL(I) = 1.0
                                                                                                     000474
                                                                                                     000475
  150 CONTINUE
                                                                                                     000476
C
       DEFINE CHANNEL BAND CODE (CHANNEL, FREQUENCY EDCE INDEX), WHERE THE FIRST CHANNEL IS CLOSEST TO THE SHORT CIRCUIT AND CORRESPONDS TO THE HIGHEST CENTER FREQUENCY, AND THE FREQUENCY EDCES ARE 1 FOR LOWER EDGE AND 2 FOR UPPER EDGE. THE VALUE OF CHBCODE CORRESPONDS TO THE FREQUENCY POINT INDEX USED AS ARCUMENT OF OMECA(I). IF THERE IS NO SPECIFICATION FOR A PARTICULAR CHANNEL, THE VALUE OF CHECODE MUST BE SET TO A
                                                                                                     000477
                                                                                                     000478
Č
                                                                                                     000479
C
                                                                                                     000480
                                                                                                     000481
                                                                                                     000482
                                                                                                     000483
        OF CHBCODE MUST BE SET TO 0.
                                                                                                     000484
                                                                                                     000485
        CIIBCODE(1,1)=31
                                                                                                     000486
        CHBCODE(1,2) = 45
                                                                                                     000487
        CIIBCODE(2, 1) = 16
                                                                                                     000488
        CHBCODE(2,2)=30
        CHBCODE(3,1)=1
                                                                                                     000489
                                                                                                     000490
        CHBCODE(3,2) = 15
                                                                                                     000491
        DEFINE THE SPECIFICATION CODE FOR INSERTION LOSS OPTIMIZATION
                                                                                                     000492
                                                                                                     000493
        (FREQUENCY INDEX, CHANNEL)
                                                                                                     000494
        DO 20 I=1,15
DO 20 J=1,3
                                                                                                     000495
                                                                                                     000496
        SPCODE(I, J) = 1
                                                                                                     000497
                                                                                                     000498
    20 CONTINUE
                                                                                                     000499
        DEFINE VALUES FOR THE SPECIFICATIONS (FREQUENCY INDEX, CHANNEL)
                                                                                                     000500
                                                                                                     000501
                                                                                                     000502
        DO 25 I=1,3
                                                                                                     000503
        SU(1,I)=2.79
                                                                                                     000504
        SU(2,1)=1.77
                                                                                                     000505
        SU(3,1)=1.41
        SU(4,1)=1.24
                                                                                                     000506
                                                                                                     000507
        DO 33 J=5,11
                                                                                                     000508
        SU(J, 1) = 1.12
                                                                                                     000509
    33 CONTINUE
        SU(12,1)=1.24
SU(13,1)=1.41
                                                                                                     000510
                                                                                                     000511
                                                                                                     000512
        SU(14,1)=1.77
                                                                                                     000513
        SU(15, I) = 2.79
                                                                                                     000514
    25 CONTINUE
                                                                                                     000515
        DEFINE WEIGHTING FACTORS CORRESPONDING TO THE SPECIFICATIONS
                                                                                                     000516
                                                                                                     000517
                                                                                                     000518
        DO 35 I=1,15
                                                                                                     000519
        DO 35 J=1,3
        WU(I,J) = 1.0
                                                                                                     000520
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

					000521		
С	35	CONTINUE					
č		ARGUMEI	YTS	S OF THE MINIMAX OPTIMIZATION(MMLC) CALL STATEMENT	$000522 \\ 000523$		
C					000524		
C		FDF2	-	NAME OF A SUBROUTINE CALCULATING MINIMAX FUNCTIONS AND	000525		
C				THEIR DERIVATIVES AT THE POINT DEFINED BY THE X VECTOR. THE NAME FDF2 IS ARBITRARY AND MUST APPEAR IN THE EXTER-	$000526 \\ 000527$		
C C				NAL STATEMENT IN THE SEGMENT CALLING MMLC1A.	000528		
Č		NV	_	INTEGER ARGUMENT WHICH MUST BE SET TO THE NUMBER OF OP-	000529		
č		•••		TIMIZATION VARIABLES. ITS VALUE MUST BE POSITIVE AND IS	000530		
Č				NOT CHANGED BY THE PACKAGE.	000531		
C		MF	-	INTEGER ARGUMENT WHICH MUST BE SET TO THE NUMBER OF RE-	090532		
C				SIDUAL FUNCTIONS DEFINING THE MINIMAX OBJECTIVE FUNCTION.	000533		
C				ITS VALUE MUST BE POSITIVE AND IS NOT CHANGED BY THE PA-	000534 000535		
C			_	CKAGE. INTEGER ARCUMENT WHICH MUST BE SET TO THE TOTAL NUMBER	000536		
C		L	_	OF EQUALITY AND INEQUALITY CONSTRAINTS. ITS VALUE MUST	000537		
č				BE POSITIVE OR ZERO AND IT IS NOT CHANGED BY THE PACKA-	000538		
č				GE.	000539		
\mathbf{c}		LEQ	-	INTEGER ARGUMENT WHICH MUST BE SET TO THE NUMBER OF EQ-	000540		
C				UALITY CONSTRAINTS. ITS VALUE MUST BE POSITIVE OR ZERO	000541		
C				AND NOT GREATER THAN NV, AND NOT CREATER THAN L. ITS VALUE IS NOT CHANGED BY THE PACKAGE.	000542 000543		
C		В	_	REAL ARRAY OF LENGTH 11C > L. THE ELEMENTS OF B MUST BE	000544		
č		ь		SET TO THE CONSTANT TERMS IN THE LINEAR CONSTRAINTS.	000545		
č				THE CONTENTS OF B ARE NOT CHANGED BY THE PACKAGE.	000546		
\mathbf{c}		C	-	REAL MATRIX OF DIMENSIONS (IIC, NV). THE FIRST L ROWS OF	000547		
C				C MUST BE SET TO THE COEFFICIENTS OF X IN THE LINEAR	000548		
Ç		***		CONSTRAINTS.	000549		
C C		IIC	CMES	INTEGER ARGUMENT WHICH MUST BE SET TO THE LENGTH OF THE ARRAY B AND TO NUMBER OF ROWS OF THE MATRIX C. ITS VA-	000550 000551		
č				LUE MUST NOT BE LESS THAN L. AND IT IS NOT CHANGED BY	000552		
č				THE PACKAGE.	000553		
Ċ		x	-	REAL ARRAY OF LENGTH AT LEAST NV WHICH, ON ENTRY, MUST	000554		
C				BE SET TO THE INITIAL APPROXIMATION OF THE SOLUTION.	000555		
C				ON EXIT X CONTAINS THE BEST SOLUTION FOUND BY THE PACK-	000556		
C		D37		ACE.	000557		
C		DX	_	REAL VARIABLE WHICH CONTROLS THE STEP LENGTH OF THE ITER- ATIVE ALCORITHM. ON ENTRY IT MUST BE SET TO AN INITIAL	000558 000559		
č				VALUE APPROXIMATELY EQUAL TO 0.1* X. THE VALUE OF DX	000560		
č				MUST BE POSITIVE. ON EXIT DX CONTAINS THE LAST VALUE OF	000561		
C				THE STEPSIZE. FOR EXTENSIVE DETAILS PLEASE REFER TO	000562		
C				REPORT SOS-82-5-U2, AUGUST 1983.	000563		
C		EPS	-	REAL VARIABLE WHICH ON ENTRY MUST BE SET TO THE REQUIRED	000564		
C				ACCURACY OF THE SOLUTION. ON EXIT EPS CONTAINS THE LENGTH OF THE LAST STEP TAKEN IN THE ITERATION.	000565 000566		
Č		MAXF	_	INTEGER VARIABLE WHICH MUST BE SET TO AN UPPER BOUND ON	000567		
č		TIPATE .		THE NUMBER OF CALLS OF FDF2. ON EXIT MAXE CONTAINS THE	000568		
$\bar{\mathbf{c}}$				NUMBER OF CALLS OF FDF THAT HAVE BEEN PERFORMED BY THE	000569		
C				PACKAGE.	000570		
C		KEQS	-	INTEGER VARIABLE WHICH MUST BE SET TO THE NUMBER OF SUC=	000571		
C				CESSIVE ITERATIONS WITH IDENTICAL SETS OF ACTIVE RESIDUAL	000572		
C				FUNCTIONS AND ACTIVE CONSTRAINTS THAT IS REQUIRED BEFORE A SWITCH TO STAGE 2 IS MADE. ON EXIT KEQS CONTAINS THE	000573 000574		
C C				NUMBER OF SWITCHES TO STAGE 2 THAT HAVE TAKEN PLACE.	000575		
č		w	_	REAL ARRAY WHICH IS USED FOR WORKING SPACE. ITS LENGTH	000576		
Ċ			•	IS GIVEN BY IW. ON EXIT THE FIRST MF ELEMENTS OF W CON-	000577		
C				TAIN THE RESIDUAL FUNCTION VALUES AT THE SOLUTION.	000578		
C		IW	-	INTEGER ARGUMENT WHICH MUST BE SET TO THE LENGTH OF W.	000579		
C				ITS VALUE MUST BE AT LEAST	000580		
C				IWR=2*MF*NV+5*NV*NV+4*MF+8*NV+4*IIC+3	000581 000582		
č				THIS PARTICULAR AND AND EARLY AND THE CONTRACTION OF	0003 0 2		
č		ICH		INTEGER ARGUMENT WHICH MUST BE SET TO THE UNIT NUMBER	000584		
C				THAT IS TO BE USED FOR THE PRINTED OUTPUT GENERATED BY	000585		

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
THE PACKAGE. IF ICH IS LESS THAN OR EQUAL TO ZERO, NO PRINTED OUTPUT WILL BE GENERATED BY THE PACKAGE. INTEGER ARGUMENT WHICH CONTROLS THE PRINTED OUTPUT GENERATED BY THE PACKAGE. FOR EXTENSIVE DETAILS PLEASE
                                                                                                                    000586
                                                                                                                    000587
00000000000000000
                                                                                                                    000588
         IPR
                                                                                                                    000589
                      REFER TO REPORT SOS-82-5-U2, AUGUST 1983.
INTEGER VARIABLE WHICH ON EXIT CONTAINS INFORMATION
                                                                                                                    000590
                                                                                                                    000591
         IFALL
                                                                                                                    000592
                       ABOUT THE SOLUTION:
                                                                                                                    000593
                       IFALL =- 2 FEASIBLE REGION IS EMPTY,
                                                                                                                    000594
                       IFALL=-1 INCORRECT INPUT DATA,
                       IFALL= 0 REGULAR SOLUTION; REQUIRED ACCURACY OBTAINED, IFALL= 1 SINGULAR SOLUTION; REQUIRED ACCURACY OBTAINED,
                                                                                                                    000595
                                                                                                                    000596
                       IFALL= 2 MACHINE ACCURACY REACHED,
IFALL= 3 MAXIMUM NUMBER OF FUNCTION EVALUATIONS REACHED,
IFALL= 4 ITERATION TERMINATED BY THE USER.
                                                                                                                    000597
                                                                                                                    000598
                                                                                                                    000599
                                                                                                                    000600
         DEFINE PARAMETERS FOR THE MMLC PACKAGE
                                                                                                                    000601
                                                                                                                    000602
                                                                                                                    000603
                                                                                                                    000604
         MF=92
                                                                                                                    000605
         L=0
                                                                                                                    000606
         LEQ=0
                                                                                                                    000607
         11C=1
                                                                                                                    000608
         DX=0.05
                                                                                                                    000609
         EPS=1.E-6
                                                                                                                    000610
         MAXF=65
                                                                                                                    000611
         KEQS=3
                                                                                                                    000612
         IW=20000
                                                                                                                    000613
         ICH=6
                                                                                                                    000614
         IPR=10
                                                                                                                    000615
         NCOUNT= 1
                                                                                                                    000616
\mathbf{C}
         CALL MMLC1A(FDF2, NV, MF, L, LEQ, B, C, IIC, X, DX, EPS, MAXE, KEQS, W, 1W, ICH,
                                                                                                                    000617
                                                                                                                    000618
                         IPR, IFALL)
                                                                                                                    000619
\mathbf{C}
                                                                                                                    000620
         STOP
                                                                                                                    000621
         END
                                                                                                                    000622
C
```

Fig. 2 (continued)

Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000623
\mathbf{C}
       SUBROUTINE FDF2(NV, MF, X, DF, F)
                                                                                                 000624
       REAL X(NV), F(MF), DF(MF, NV)
                                                                                                 000625
       REAL X(NV), F(III), BI(III, NV)

REAL OMECA(47), SURI.(47), SLRL(47), WURL(47), WLRL(47),

SU(20,16), SL(20,16), WU(20,16), WL(20,16)

INTEGER RLSCODE(47), SPCODE(20,16), CHBCODE(16,2)

REAL CM(16,8,8), WGL(16), DRL(100), FIL(16), DIL(16,100)
                                                                                                 000626
                                                                                                 000627
                                                                                                 000628
                                                                                                 000629
        INTEGER IR(16), IRT(16), LC(16,36), KC(16,36)
                                                                                                 000630
       INTEGER IPN1(16), IPN2(16), IWG(16)
REAL WO(16), BW(16), PN1(16), PN2(16), GL(16)
COMMON / BLK2/CM, WGL
                                                                                                 000631
                                                                                                 000632
                                                                                                 000633
        COMMON /BLK1/WO, BW, PN1, PN2, CL, VS, RS, P12, WIDTH, NP1
                                                                                                 000634
       COMMON /BLK3/OMEGA, SURL, SLRL, WURL, WLRL, SU, SL, WU, WL,
                                                                                                 000635
                        RLSCODE, SPCODE, NCOUNT, MODE, NCH, MO,
                                                                                                 000636
                        NFREQ, NFRL, CHBCODE, IFLAGJS, IFLAGDP, IDISPER
                                                                                                 000637
       COMMON/BLK8/IR, IRT, IPN1, IPN2, IWC, LC, KC
                                                                                                 000638
                                                                                                 000639
C
        UPDATE OPTIMIZATION VARIABLES
                                                                                                 000640
                                                                                                 000641
        1F(1RT(1).EQ.0)GO TO 20
                                                                                                 000642
        IF(IR(1).EQ.0)GO TO 11
                                                                                                 000643
        IR1= IR( 1)
                                                                                                 000644
       DO 10 IV=1, IR1
                                                                                                 000645
       CM(1,LC(1,IV),KC(1,IV))=X(IV)
                                                                                                 000646
    10 CONTINUE
                                                                                                 000647
                                                                                                 000648
    11 1F(1PN1(1).EQ.0)GO TO 12
        IV = IR(1) + IPN1(1)
                                                                                                 000649
       PN1(1) = X(1V)
                                                                                                 000650
    12 IF(IPN2(1).EQ.0)GO TO 13
                                                                                                 000651
        IV = IR(1) + IPN1(1) + IPN2(1)
                                                                                                 000652
       PN2(1) = X(IV)
                                                                                                 000653
    13 IF(IWG(1).EQ.0)GO TO 14
                                                                                                 000654
        IV= IR(1) + IPN1(1) + IPN2(1) + IWG(1)
                                                                                                 000655
        WGL(1) = X(IV)
                                                                                                 000656
    14 CONTINUE
                                                                                                 000657
\mathbf{C}
                                                                                                 000658
   20 CONTINUE
                                                                                                 000659
       DO 40 I=2,NCH
IF(IRT(I).EQ.0)CO TO 40
                                                                                                 000660
                                                                                                 000661
        IX= IRT( I-1)
                                                                                                 000662
        IF(IR(I).EQ.0)CO TO 15
                                                                                                 000663
        IRI=IR(I)
                                                                                                 000664
       DO 30 IP=1, IRI
                                                                                                 000665
        IXX=IX+IP
                                                                                                 000666
       CM(1,LC(1,IP),KC(1,IP))=X(IXX)
                                                                                                 000667
   30 CONTINUE
                                                                                                 000668
   15 IF(IPN1(I).EQ.0)GO TO 16
                                                                                                 000669
        IXX = IX + IR(I) + IPN1(I)
                                                                                                 000670
       PN1(1)=X(1XX)
                                                                                                 000671
    16 IF(IPN2(I).EQ.0)GO TO 17
                                                                                                 000672
        1XX = 1X + 1R(1) + 1PN1(1) + 1PN2(1)
                                                                                                 000673
       PN2(I)=X(IXX)
                                                                                                 000674
       IF(IWG(I).EQ.0)GO TO 18
                                                                                                 000675
        IXX=IX+IR(I)+IPN1(I)+IPN2(I)+IWG(I)
                                                                                                 000676
        WGL(1) = X(1XX)
                                                                                                 000677
   18 CONTINUE
                                                                                                 000678
\mathbf{C}
                                                                                                 000679
    40 CONTINUE
                                                                                                 000680
C
                                                                                                 000681
       DEFINE MINIMAX FUNCTIONS AND THEIR GRADIENTS
                                                                                                 000682
\mathbf{c}
\mathbf{C}
                                                                                                 000683
       NCHAN=NCH
                                                                                                 000684
       MORDER= MO
                                                                                                 000685
        KFRL=0
                                                                                                 000686
       KFUN=NFRL
                                                                                                 000687
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

```
000688
      DO 100 I=1, NFREQ
      FREQ=OMEGA(I)
                                                                                   000689
                                                                                   000690
C
      CALL SIMCRD2(FREQ, FRL, DRL, FIL, DIL, NCHAN, MORDER, I, IFLAGJS,
                                                                                   000691
                                                                                   000692
                    IFLAGDP, IDISPERO
                                                                                   000693
C
      IF(MODE.EQ. 1) GO TO 199
                                                                                   000694
      IF(RLSCODE(I).EQ.0)CO TO 199
                                                                                   000695
      IF(RLSCODE(I).EQ.-1)GO TO 70
                                                                                   000696
      IF(RLSCODE(I).EQ. 1) CO TO 75
                                                                                   000697
                                                                                   000698
      KFRL=KFRL+1
                                                                                   000699
      F(KFRL) = WURL(I) * (FRL-SURL(I))
      DO 80 K1=1,NV
                                                                                   000700
      DF(KFRL, K1) = WURL(I) *DRL(K1)
                                                                                   000701
                                                                                   000702
   80 CONTINUE
                                                                                   000703
      KFRL= KFRL+ 1
      F(KFRL) = -WLRL(I) * (FRL-SLRL(I))
                                                                                   000704
      DO 85 K2=1,NV
                                                                                   000705
      DF(KFRL, K2) = -WLRL(I) *DRL(K2)
                                                                                   000706
                                                                                   000707
   85 CONTINUE
                                                                                   000708
      GO TO 199
                                                                                   000709
   70 KFRL=KFRL+1
      F(KFRL) = -WLRL(I) * (FRL-SLRL(I))
                                                                                   000710
      DO 90 K3=1,NV
                                                                                   000711
      DF(KFRL,K3)=-WLRL(I)*DRL(K3)
                                                                                   000712
                                                                                   000713
   90 CONTINUE
                                                                                   000714
      GO TO 199
                                                                                   000715
   75 KFRL=KFRL+1
      F(KFRL) = WURL(I) * (FRL-SURL(I))
                                                                                   000716
                                                                                   000717
      DO 95 K4=1,NV
      DF(KFRL, K4) = WURL(I) *DRL(K4)
                                                                                   000718
   95 CONTINUE
                                                                                   000719
                                                                                   000720
  199 CONTINUE
                                                                                   000721
      IF(MODE.EQ.0)GO TO 100
                                                                                   000722
      DO 105 J=1, NCH
      NCHECK= 0
                                                                                   000723
      IF(I.GE.CHBCODE(J,1).AND.I.LE.CHBCODE(J,2))NCHECK=1
IF(NCHECK.EQ.0)GO TO 105
                                                                                   000724
                                                                                   000725
                                                                                   000726
      K=I-CHBCODE(J, 1)+1
      IF(SPCODE(K, J).EQ.0)GO TO 105
                                                                                   000727
      IF(SPCODE(K, J).EQ.-1)CO TO 110
                                                                                   000728
                                                                                   000729
      IF(SPCODE(K, J).EQ. 1)GO TO 115
                                                                                   000730
      KFUN=KFUN+1
                                                                                   000731
      F(KFUN) = WU(K, J) * (FIL(J) - SU(K, J))
      DO 120 I1=1,NV
                                                                                   000732
      DF(KFUN, I1) = WU(K, J) *DIL(J, I1)
                                                                                   000733
                                                                                   000734
  120 CONTINUE
                                                                                   000735
      KFUN=KFUN+1
                                                                                   000736
      F(KFUN) = -WL(K,J)*(FIL(J)-SL(K,J))
      DO 125 I2=1.NV
                                                                                   000737
      DF(KFUN, 12) = -WL(K, J) *DIL(J, 12)
                                                                                   000738
                                                                                   000739
  125 CONTINUE
                                                                                   000740
      GO TO 105
                                                                                   000741
  110 KFUN=KFUN+1
                                                                                   000742
      F(KFUN) = -WL(K,J)*(FIL(J)-SL(K,J))
      DO 130 I3=1,NV
                                                                                   000743
      DF(KFUN, 13) =-WL(K, J)*D1L(J, 13)
                                                                                   000744
                                                                                   000745
  130 CONTINUE
                                                                                   000746
      GO TO 105
                                                                                   000747
  115 KFUN=KFUN+1
      F(KFUN) = WU(K, J) * (FIL(J) - SU(K, J))
                                                                                   000748
                                                                                   000749
      DO 135 I4=1,NV
      DF(KFUN, 14) = WU(K, J) *DIL(J, 14)
                                                                                   000750
                                                                                   000751
  135 CONTINUE
                                                                                   000752
  105 CONTINUE
```

Fig. 2 (continued) Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

100 CONTINUE NCOUNT=NCOUNT+1 RETURN END

000753 000754 000755 000756

Fig. 2 (continued)

Listing of MXSOS2 and the subroutine FDF2 arranged for optimization.

PAGE: TIME : 13.22.18. DATE: 84/02/27. LINEARLY CONSTRAINED MINIMAX OPTIMIZATION (MMLC PACKAGE) (V:82.04) MULTIPLEXER PROBLEM MXTST6C INPUT DATA 45 92 NUMBER OF FUNCTIONS (M) Ø TOTAL NUMBER OF LINEAR CONSTRAINTS (L) NUMBER OF EQUALITY CONSTRAINTS (LEQ) 5.000E-02 1.000E-06 ACCURACY (EPS) 65 MAX NUMBER OF FUNCTION EVALUATIONS (MAXF) . . 3 NUMBER OF SUCCESSIVE ITERATIONS (KEQS) . . 20000 10 STARTING POINT : FUNCTION VALUES VARIABLES 1.376617388788E+01 1.210725700872E+01 5.939500000000E-01 3 1.022508793930E+01 3 9.539332832200E+00 5.35140000000E-01 4 9.242400838775E+00 ø. 5 8.322091837541E+00 4.247100000000E-01 4.652810008359E+00 -3.996700000000E-01 8 3.867665333761E+00 3.126529123101E+00 8.337100000000E-01 -3.154641846770E+00 10 10 -6.266536400448E+00 7.63130000000E-01 11 11 -4.410253562100E+00 12 ø. -3.953338929107E+00 8.364627905651E-01 13 -6.912146772112E+00 -1.435396827914E+01 1.046183540303E+00 14 15 6.410000000000E-01 15 3.119334122250E+00 16 16 -7.712442950287E-01 5.939500000000E-01 17 18 -2.665683411725E+00 18 -9.916907250456E-01 5.35140000000E-01 19 19 -1.396690512709E+00 20 Ø. 21 22 4.247100000000E-01 -4.630832122157E+00 -3.996700000000E-01 -1.427203203127E+01 23 24 -7.070225476307E+00 23 -3.329177425626E+01 B.337100000000E-01 -3.455972276484E+00 25 25 7.631300000000E-01 26 -2.209056470880E+00 26 27 -3.964880382496E+00 Ø 8.364627905651E-01 28 -4.320417138471E+00 28 7.904485223746E-01 1.046183540303E+00 29 1.344999825989E+00 30 6.31000000000E-01

Fig. 3 Printout of results for the three-channel optimization problem.

DATE: 64/02/27. TIME: 13.22.18. LINEARLY CONSTRAINED MINIMAX OPTIMIZATION (MMLC PACKAGE)

PAGE: 2 (V:82.04)

MULTIPLEXER PROBLEM MXTST6C

```
6.789481124746E+00
      5.939500000000E-01
                                            3.095280387081E+00
                                      32
                                            3.070596484094E+00
                                      33
33
                                            3.361977223309E+00
      5.35140000000E-01
                                      34
35
                                             1.677997351072E+00
                                      35
      4.247100000000E-01
                                           -3.810497037170E-01
36
37
     -3.996700000000E-01
                                      37
                                            3.350534703400E+00
                                            4.529973627815E+00
4.448045941187E+00
B.155693274774E+00
38
                                      38
      B.337100000000E-01
39
                                      39
40
41
42
                                      40
                                            9.198413795891E+00
      7.63130000000E-01
                                      42
                                            9.507740957318E+00
      8.364627905651E-01
                                      43
                                             1.010188526819E+01
43
                                            1.199833518187E+91
1.373588782520E+01
                                      44
45
      1.046183540303E+00
      6.330000000000E-01
                                            5.881726899296E-01
                                            5.606073452421E+00
                                            3.397343518583E-01
                                      49
                                            4.272216573252E-01
                                            2.547630170446E-01
                                      50
                                            2.088061948320E-01
                                      51
52
                                            2.171340363827E-01
                                            9.014140138119E-02
                                      53
                                           -1.459429271873E-01
                                           -1.840639900810E-01
                                      55
                                           -1.722974051960E-01
-1.668893351765E-01
                                      56
57
                                      58
                                           -1.130228510226E-01
                                           -1.273117826421E-01
                                      59
                                           -1.326792957479E-01
                                           -2.116054575533E-01
                                           -5.411054170164E-01
                                           -1.280821750845E-01
-7.401366925222E-02
-6.622988776045E-02
                                      63
                                      64
                                      65
                                           -6.449319252491E-02
                                      66
                                           -5.698638585295E-02
                                           -1.450000956344E-01
-2.378459752295E-01
-2.557855803587E-01
-2.432559645821E-01
                                      68
                                      69
                                      70
71
                                           -1.535450722965E-01
                                           -8.290833706865E-02
                                           -1.117050256841E-01
-1.204251798056E-01
-1.527941620359E-01
                                      75
                                      76
                                      77
                                           -4.575620274459E-01
                                           -2.520671425147E-02
                                           -2.745971306157E-02
                                           -6.062636513491E-03
-1.005897550820E-02
                                      80
                                      81
                                           -3.099896085189E-92
                                      82
                                      83
                                           -1.275063411426E-01
                                           -1.557719685368E-01
                                      84
                                      85
                                           -1.569355189001E-01
                                      86
                                           -1.439201763664E-01
```

Fig. 3 (continued)

Printout of results for the three-channel optimization problem.

87

88

8.470500807513E-02

2.194009772458E-01

DATE: 84/02/27. TIME: 13.22.18. LINEARLY CONSTRAINED MINIMAX OPTIMIZATION (MMLC PACKAGE)

PAGE: 3 (V:82.04)

MULTIPLEXER PROBLEM MXTST6C

89	2.125154002832E-01
90	2.481392931055E-01
91	4.141733127239E-01
92	3.340379043190E-01

SOLUTION

	VARIABLES	k.	FUNCTION VALUES
1	-6.044027292422E-02	1	-2.600085010356E+00
ż	7.325746555378E-01	2	-2.156044754964E-01
3	-6.939183412333E-02	3	-9.891552359371E-01
4	5.598321723712E-01	4	-2.157316419238E-01
5	1.283843451561E-02	5	-3.991827490066E-01
6 .	4.124508825067E-01	6	-2.181897820656E+00
7	-4.717569056358E-01	7	-3.598592803821E+00
8	4.182049301334E-02	8	-2.154877885846E-01
9	8.863784882748E-01	9	-1.966507434300E+00
10	5.792510733123E-02	10	-1.395234024877E+01 -1.518816774199E+01
11	7.824970565547E-01 1.346337934973E-02	11 12	-9.637264457316E+90
12 13	1.099062965387E+00	13	-8.808437172878E+00
14	1.082354644330E+00	14	-5.262799505118E+00
15	6.736038935441E-01	15	-3.502156885571E-01
16	1.244478609904E-01	16	-2.135127807545E-01
17	6.360872160508E-01	17	-5.223925285351E+00
18	2.427646151828E-03	18	-5.718853056122E+00
19	5.573920279614E-01	19	-5.897830464558E+00
20	-4.178151147506E-03	20	-9.064871534898E+00
21	3.962409124580E-01	21	-1.223432408220E+01
22	-5.640839269006E-01	22	-2.647233965705E+00
23	-8.155794850229E-03	23	-2.153255352886E-01
24	9.544758710356E-01	24	-3.241526245149E+00
25	2.981639393973E-02	25	-1.724416757945E+01
26	7.639824046422E-01	26	-1.813109509977E+01
27	-3.907219043917E-03	27	-1.269197050951E+01 -1.080341247641E+01
28	9.161514328102E-01	28 29	-6.132157719754E+00
29	1.111196296523E+00	30	-1.911168646363E+00
30	5.954929663106E-01 1.944047789431E-01	31	-2.152583924184E-01
31	6.707241120483E-01	32	-8.217857458398E+00
32 33	4.771501445755E-02	33	-5.225796973917E+90
34	5.597795068260E-01	34	-6.282945195725E+00
35	-3.131345747253E-02	35	-1.207969028979E+01
36	3.990357533710E-01	36	-1.015363029176E+01
37	-5.117829489607E-01	37	-7.797221497376E-01
38	-6.068193434428E-02	38	-2.156857538054E-01
39	8.945390524320E-01	39	-5.101679674491E+00
40	-3.206330870620E-02	40	-1.997019524539E+00
41	7.650458312043E-01	41	-2.158398189908E-01
42	-2.231361222110E-02	42	-2.156920079480E-01
43	8.768413389939E-01	43	-1.054938612420E+00
44	1.101422627599E+00	44	-2.162664418719E-01
45	5.914808559808E-01	45	-1.415136100738E+00
		46	-2.934662010578E+00
		47	-4.141597151497E-01

Fig. 3 (continued)

Printout of results for the three-channel optimization problem.

DATE: 84/02/27. TIME: 13.22.18. LINEARLY CONSTRAINED MINIMAX OPTIMIZATION (MMLC PACKAGE)

PAGE: 4 (V:82.04)

MULTIPLEXER PROBLEM MXTST6C

	4	8	_	8.	34	71	19	16	93	67	E-	0 1			
	-	9			42										
		0			25										
		1			72										
		2			27										
		3			86										
		4			40	-									
		5			26										
		6			13										
		7			73										
	_	8			15										
		9			45										
		ó			76										
		1			65										
		2			15										
		3			1.5										
		4			81										
		5			83										
		6			47										
		7			15										
		8			72										
	_	-			10										
		9			98										
					10										
		'1 '2			70										
	-	_			15										
	_	3													
		4			50										
		5			85										
	-	6			74										
		7			30										
		8			15										
		'9			61										
	_	30			63										
		3 1			38										
	_	32			1.5										
		33			74										
	_	14		_	1.1										
		15			33										
	-	36			54										
	ε	37	-	2.	94	09	87	37	88	00	E-	01			
	ε	88	-	2.	35	37	41	91	17	50	E-	Ø 1			
	ε	39			83										
	9	0	-	з.	40	89	65	62	69	62	E-	01			
	9	1	-	4.	69	40	10	78	91	91	E-	0 1			
	9	2	-	9.	21	81	29	40	5 1	97	E-	0 1			
•	•				•	•			•	•	•	•	•	•	
•	•	•	٠	•	•	•	•	٠	•	•	•	•	•	•	

Fig. 3 (continued)

Printout of results for the three-channel optimization problem.

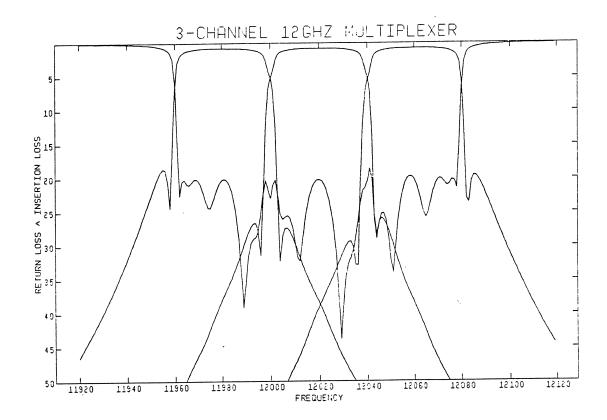


Fig. 4 Responses in dB of the three-channel multiplexer with optimized spacings, input and output transformer ratios and coupling parameters as well as cavity resonant frequencies. See the text for data.

SUBROUTINE FDF2

SUBROUTINE FDF2 (NV, MF, X, DF, F)

Purpose

FDF2 is the name of a subroutine calculating the minimax functions $f_i(\mathbf{x})$ and their derivatives $\partial f_i(\mathbf{x})/\partial \mathbf{x}_j$ at the point \mathbf{x} corresponding to X(1), X(2), ..., X(NV), and storing the values in the following way:

$$\begin{split} F(I) &= f_{\underline{I}}(\mathbf{x}) \,, & I &= 1, ..., MF \,, \\ DF(I,J) &= \partial f_{\underline{I}}(\mathbf{x}) / \partial x_{,J} \,\,, & I &= 1, ..., MF \,, \, J &= 1, ..., NV \,. \end{split}$$

The name FDF2 must appear in the EXTERNAL statement in the main segment calling MMLC1A. The subroutine updates the multiplexer parameters which are the optimization variables.

List of Arguments

NV is an integer argument, which must be set to the number of optimization variables. Its value must be positive and is not changed by the package.

MF is an integer argument, which must be set to the number of residual functions defining the minimax objective function. Its value must be positive and is not changed by the package.

X is a real array of length at least NV, which must contain the optimization variables values used for calculating the minimax functions and their derivatives.

DF is a real array of dimensions at least MF by NV. It must contain the derivatives of minimax functions at the point \mathbf{x} corresponding to $\mathbf{X}(1)$, $\mathbf{X}(2)$, ..., $\mathbf{X}(\mathbf{NV})$.

F is a real array of length at least MF. It must contain the values of minimax functions calculated at the point x corresponding to X(1), X(2), ..., X(NV).

Common Blocks

COMMON/BLK1/

WO, BW, PN1, PN2, GL, VS, RS, PI2, WIDTH, NP1

COMMON/BLK2/

CM, WGL .

COMMON/BLK3/

OMEGA, SURL, SLRL, WURL, WLRL, SU, SL, WU, WL,

RLSCODE, SPCODE, NCOUNT, MODE, NCH, MO, NFREQ,

NFRL, CHBCODE, IFLAGJS, IFLAGDP, IDISPER

COMMON/BLK8/

IR, IRT, IPN1, IPN2, IWG, LC, KC

All variables and arrays, except NP1 and NCOUNT, have been explained in previous sections.

NCOUNT is an integer variable, which is increased by 1 every time the subroutine FDF2 is called.

NP1 is an integer variable, which is equal to NCH + 1.

Organization of the Subroutine

The approach used to create the minimax functions has been described in the MULTIPLEXER OPTIMIZATION section, subsection Formulation of the Problem. Here, we present flow diagrams to expose the actual organization of FDF2.

Subroutine FDF2 begins, as shown in Fig. 1, by assigning the physical variables associated with the first channel. Thus, the first IRT(1) variables in the X vector coming from MMLC are used to update the corresponding elements of matrix $CM(1, \cdot, \cdot)$, PN1(1), PN2(1) and WGL(1), whichever were declared variable in the main segment. IR(1) is the number of variables in $CM(1, \cdot, \cdot)$. The IF statements clearly ascertain whether a particular physical parameter is a variable or not.

Figure 2 proceeds exactly as in Fig. 1, except that all remaining channels are treated from 2 to NCH.

Figure 3 shows the assignment of the number of channels and the order of the filters, followed by the initialization of the minimax function counter KFRL due to return loss and

the total minimax function counter KFUN. A loop to call SIMGRD2 is initiated on a frequency by frequency point basis, details of the processing of the results of which follow in ensuing figures. The remaining part of Fig. 3 shows the updating of the number of function evaluations (one function evaluation \equiv a complete frequency response simulation and sensitivity analysis) NCOUNT followed by a return to MMLC.

Figure 4 shows the setting of the frequency value FREQ and the call to SIMGRD2.

Mode = 1 indicates that return loss is not desired. Otherwise, we go to the questions relating to RLSCODE and ask whether no specification, a lower specification or an upper specification is required. Figure 4 implements the minimax function and gradients for an upper return loss specification, followed immediately by the corresponding statements for the simultaneous lower return loss specification.

Figure 5 implements the minimax function and gradients corresponding to having a lower return loss specification only.

Figure 6 is as Fig. 5 but corresponds to an upper return loss specification.

Figure 7 initiates the channel by channel (at the single frequency under consideration) implementation of insertion loss function and gradients processed appropriately to upper and lower minimax error functions if $MODE \neq 0$. An important check is which channels a particular frequency point needs to be considered for. When NCHECK = 1 we ask for possible specifications at the Ith frequency and Jth channel.

Figure 7 continues to process simultaneous upper and lower response specifications on insertion loss for the Kth sample point associated with the Jth channel.

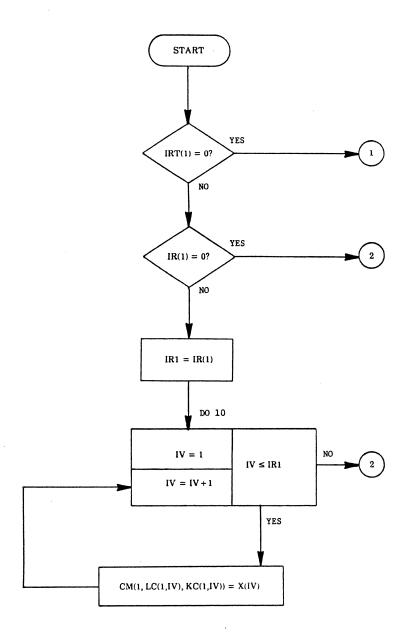
Figure 8 implements the minimax function and gradients corresponding to having a lower insertion loss specification only at the Kth point of the Jth channel (frequency point I).

Figure 9 is as Fig. 8 but corresponds to an upper insertion loss specification only.

In Figs. 5-9 it is clear that KFUN is continually incremented by 1 every time a new insertion loss minimax error function is added to the set, just as in Figs. 3 and 4 the index

KFRL is incremented whenever a new minimax error function due to return loss is added to the set.

The complete listing of the subroutine FDF2 is shown in the section MULTIPLEXER OPTIMIZATION: EXAMPLE.



- 90 -

 $Fig.\ 1 \qquad Assignment\ of\ variables\ for\ the\ first\ channel.$

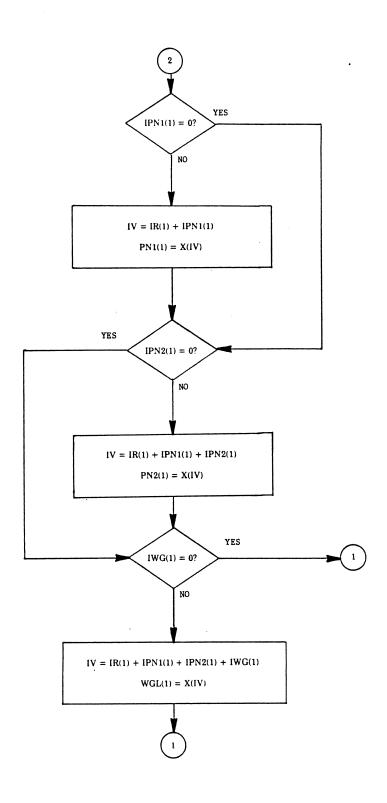


Fig. 1 (continued)

Assignment of variables for the first channel.

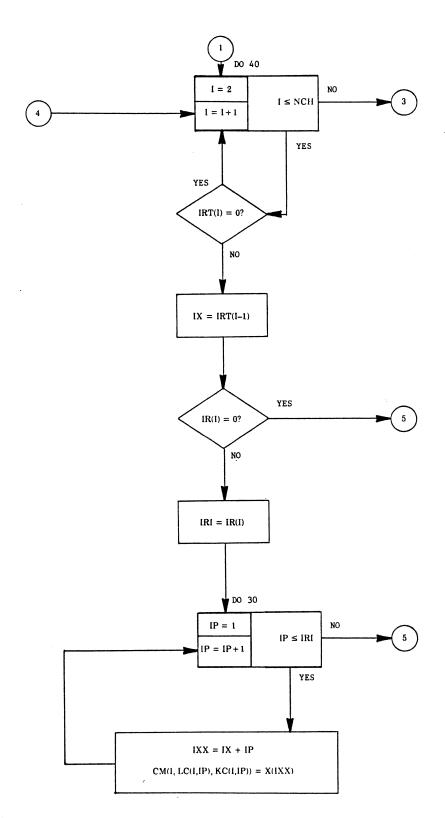


Fig. 2 Assignment of variables for the remaining channels.

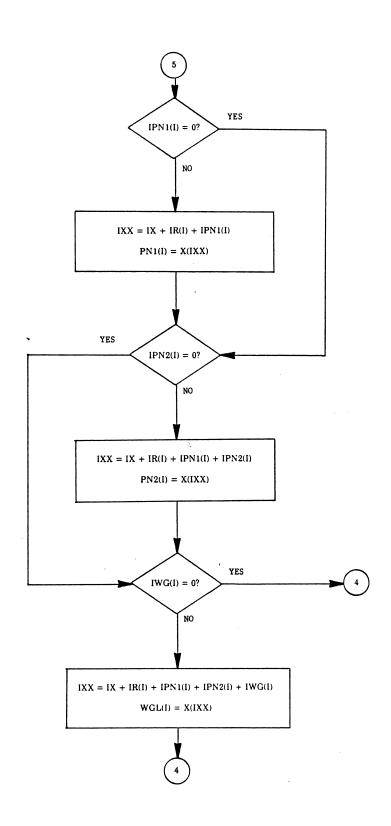


Fig. 2 (continued) Assignment of variables for the remaining channels.

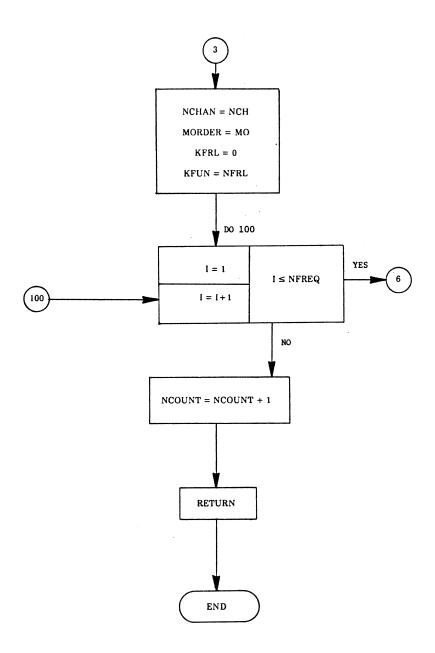
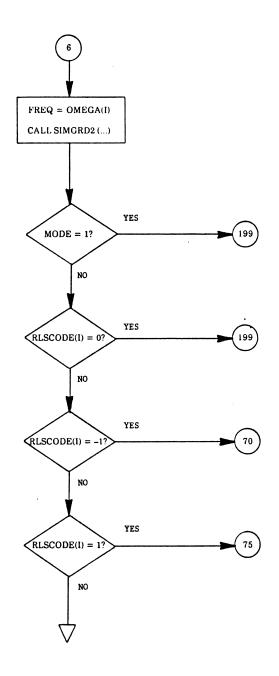


Fig. 3 Initiation of the loop to call SIMGRD2.



 $Fig.\ 4 \qquad Call\ to\ SIMGRD2\ and\ processing\ of\ simultaneous\ return\ loss\ specifications.$

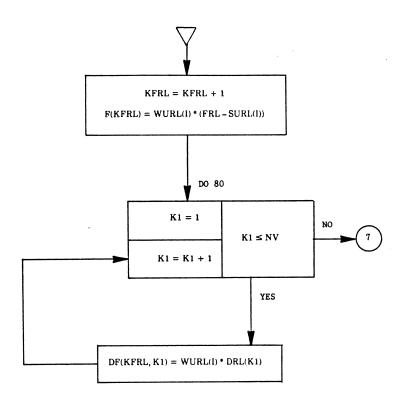


Fig. 4 (continued) Call to SIMGRD2 and processing of simultaneous return loss specifications.

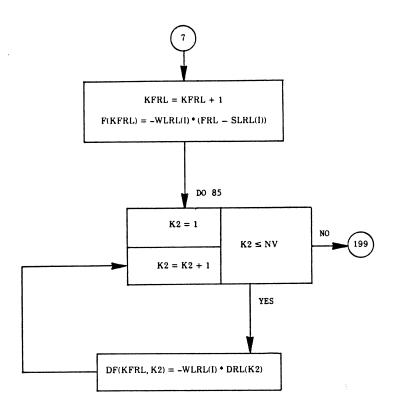


Fig. 4 (continued) Call to SIMGRD2 and processing of simultaneous return loss specifications.

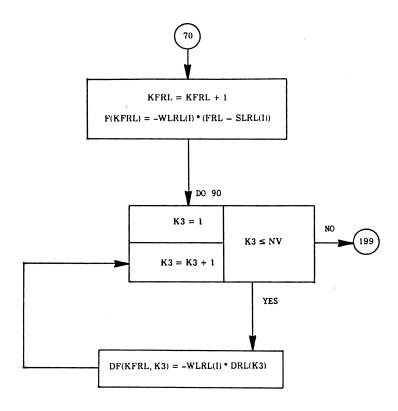


Fig. 5 Assembly of minimax functions due to lower return loss specification only.

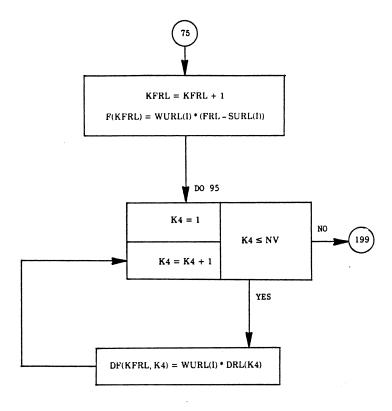


Fig. 6 Assembly of minimax functions due to upper return loss specification only.

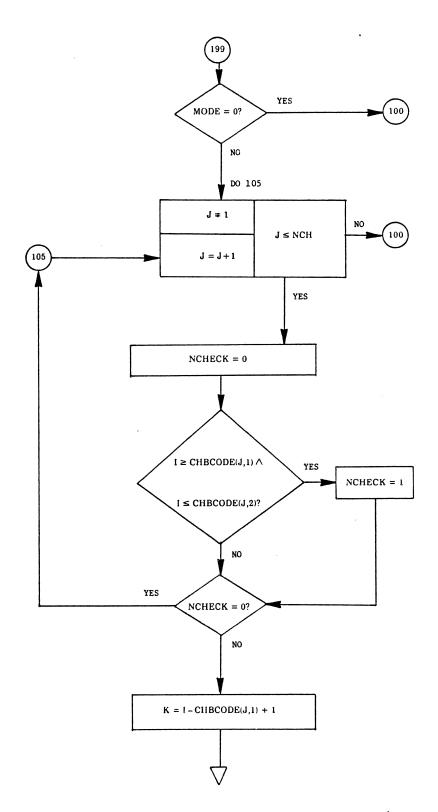


Fig. 7 Processing of channel by channel simultaneous insertion loss specifications.

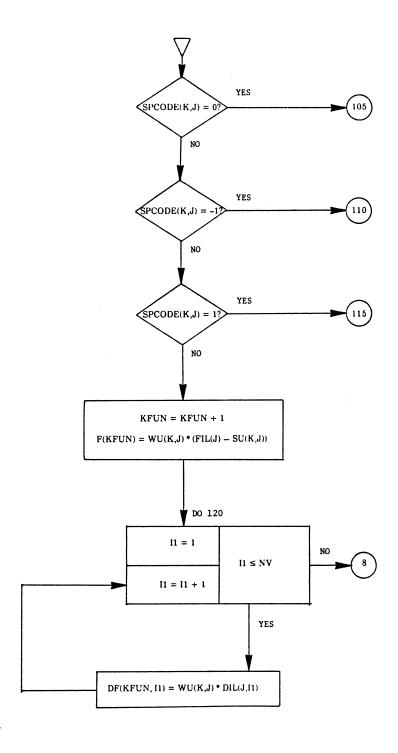


Fig. 7 (continued) Processing of channel by channel simultaneous insertion loss specifications.

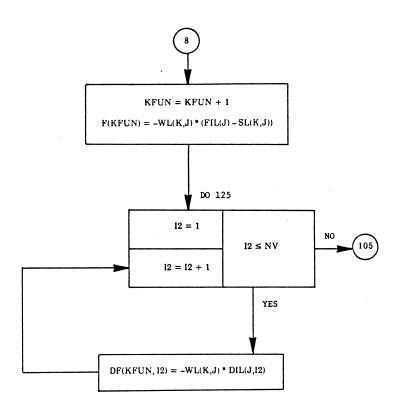


Fig. 7 (continued) Processing of channel by channel simultaneous insertion loss specifications.

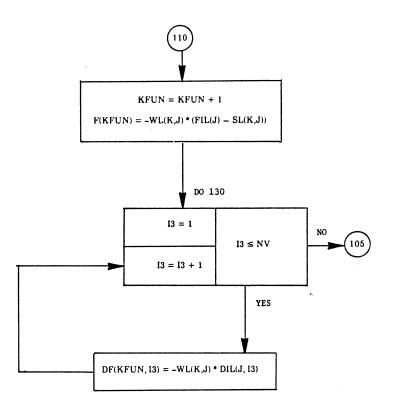


Fig. 8 Assembly of minimax functions due to lower insertion loss specifications only.

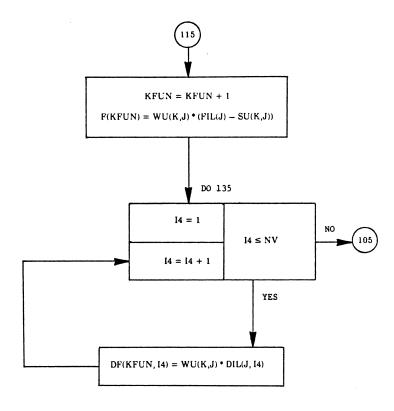


Fig. 9 Assembly of minimax functions due to upper insertion loss specifications only.

SPECIAL FEATURES OF SUBROUTINE ARGUMENTS

Introduction

This section describes some special features related to some subroutine arguments.

These features should be studied and referred to frequently from the subsequent sections as if the corresponding comments and explanations are footnotes.

Features Designed as Footnotes

- * Arrays designed by * are vectors or matrices corresponding to different channels, with the first dimension identifying the channel.
- Arrays denoted by ⁺ correspond to 2×2 matrices. The last dimension, which varies from 1 to 4, identifies the element of the matrix. The (1,1), (1,2), (2,1) and (2,2) elements are numbered 1, 2, 3 and 4, respectively.
- † Variables and arrays denoted by † are intermediate constants needed for response and/or sensitivity formulas. They are used in 3 different ways.
 - Used only in the subroutine in which they are calculated. In this case, they are not among the arguments of the subroutine and are not dimensioned for the channel number.
 - 2) Used both in the subroutine in which they are calculated and subsequent subroutines. These are usually common factors needed for both the response and its sensitivity formula. They are arguments of subroutines and the arrays are dimensioned for the channel number.
 - 3) Used only in the subsequent subroutines. There are only a few such variables or arrays in MXSOS2 and they can be eliminated in an improved program.

Notice that the names of the † variables or arrays, except for Y3SQ, always starts with the character "H", and the INTERMEDIATE VARIABLES section could be referred to for mathematical expressions corresponding to these variables.

SUBROUTINE FILTER

SUBROUTINE FILTER (N, M, Z, P, Q)

Purpose

This subroutine solves two systems of linear equations, namely,

$$\mathbf{Z} \mathbf{p} = \mathbf{e}_1 \quad \text{and} \quad \mathbf{Z} \mathbf{q} = \mathbf{e}_m$$
 (1)

for all channels at a given frequency, where

$$\mathbf{e}_{1} \stackrel{\Delta}{=} \begin{bmatrix} 1 \\ 0 \\ . \\ . \\ 0 \end{bmatrix} , \qquad \mathbf{e}_{m} \stackrel{\Delta}{=} \begin{bmatrix} 0 \\ 0 \\ . \\ . \\ . \\ 1 \end{bmatrix}$$
 (2)

Theory

Using the narrow-band unterminated model of the multi-cavity filter given by [1]

$$ZI = V (3)$$

the s.c. admittance matrix y is obtained from [1, 2]

$$\mathbf{y} = \begin{bmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} \\ \mathbf{y}_{21} & \mathbf{y}_{22} \end{bmatrix} = \begin{bmatrix} (\mathbf{Z}^{-1})_{11} & (\mathbf{Z}^{-1})_{1m} \\ (\mathbf{Z}^{-1})_{m1} & (\mathbf{Z}^{-1})_{mm} \end{bmatrix}$$
(4)

Our objective is to calculate y and its sensitivities w.r.t. any variable φ . To facilitate this we adopt a computational approach similar to the one introduced to circuit theorists by Branin [3] and which involves only simple matrix manipulations. Starting with y_{11} , we have

$$y_{11} = (Z^{-1})_{11} = e_1^T Z^{-1} e_1 = e_1^T p = p_1,$$
 (5)

where \mathbf{p}_1 is the first component of \mathbf{p} in the solution of

$$\mathbf{Z} \mathbf{p} = \mathbf{e}_{1} \tag{6}$$

and

$$\frac{\partial \mathbf{y}_{11}}{\partial \Phi} = \frac{\partial (\mathbf{Z}^{-1})_{11}}{\partial \Phi} = \mathbf{e}_{1}^{\mathrm{T}} \frac{\partial (\mathbf{Z}^{-1})}{\partial \Phi} \mathbf{e}_{1} = -\mathbf{e}_{1}^{\mathrm{T}} \mathbf{Z}^{-1} \frac{\partial (\mathbf{Z})}{\partial \Phi} \mathbf{Z}^{-1} \mathbf{e}_{1} = -\mathbf{p}^{\mathrm{T}} \frac{\partial \mathbf{Z}}{\partial \Phi} \mathbf{p} . \tag{7}$$

Similarly, we can find y_{12} , y_{21} , y_{22} and their sensitivities. Taking into account that Z is symmetric and solving the system

$$\mathbf{Z}\,\mathbf{q}=\mathbf{e}_{\mathrm{m}}\,,\tag{8}$$

the results can be summarized as [4]:

$$\mathbf{y} = \begin{bmatrix} \mathbf{p}_1 & \mathbf{q}_1 \\ \mathbf{q}_1 & \mathbf{q}_m \end{bmatrix} \tag{9}$$

and

$$\frac{\partial \mathbf{y}}{\partial \Phi} = \begin{bmatrix} -\mathbf{p}^{\mathrm{T}} \frac{\partial \mathbf{Z}}{\partial \Phi} \mathbf{p} & -\mathbf{q}^{\mathrm{T}} \frac{\partial \mathbf{Z}}{\partial \Phi} \mathbf{p} \\ -\mathbf{q}^{\mathrm{T}} \frac{\partial \mathbf{Z}}{\partial \Phi} \mathbf{p} & -\mathbf{q}^{\mathrm{T}} \frac{\partial \mathbf{Z}}{\partial \Phi} \mathbf{q} \end{bmatrix}.$$
(10)

It is clear that the solution vectors \mathbf{p} and \mathbf{q} are needed for solutions of (9) and (10).

List of Arguments

- N is the number of multiplexer channels.
- M is the order of the matrix (order of the filters).
- Z is the impedance matrix at a given frequency. It is a three-dimensional array with the first dimension corresponding to the channel number. Therefore, it contains the elements of impedance matrices for all channels.
- P is the solution vector to the system given by (6). It contains the solutions for all channels, hence it is a two-dimensional array with the first dimension identifying the channel number.
- Q contains the solutions to (8) for all channels in the same fashion as P above.

Related Software

This subroutine is called from SIMUL and SIMGRD2 and it calls CSOLLU for the solution of linear systems of equations.

Comments

- 1) The solution is obtained on a channel by channel basis.
- The solution for the system defined by (6) requires LU factorization with Forward-Backward Substitutions (FBS), however, using the same LU factors, the solution for q requires only FBS.

References

- [1] A.E. Atia and A.E. Williams, "New types of waveguide bandpass filters for satellite applications", COMSAT Technical Review, vol. 1, 1971, pp. 21-43.
- [2] M.H. Chen, "Singly terminated pseudo-elliptic function filter", <u>COMSAT Technical</u> Review, vol. 7, 1977, pp. 527-541.
- [3] F.H. Branin, Jr., "Network sensitivity and noise analysis simplified", <u>IEEE Trans.</u> Circuit Theory, vol. CT-20, 1973, pp. 285-288.
- [4] J.W. Bandler, S.H. Chen, S. Daijavad and W. Kellermann, "Optimal design of multicavity filters and contiguous-band multiplexers", <u>Proc. 14th European Microwave Conf.</u>, (Liège, Belgium, Sept. 1984).

```
SUBROUTINE FILTER(N, M, Z, P, Q)
                                                                                          000001
                                                                                          000002
CCC
        PERFORM ANALYSES FOR ALL CHANNELS
                                                                                          000003
                                                                                          000004
           NUMBER OF CHANNELS
                                                                                          000005
C
           ORDER OF MATRIX
                                                                                          000006
           IMPEDANCE MATRIX
                                                                                          000007
\mathbf{c}
                                                                                          009008
        COMPLEX Z(16,8,8), ZT(8,8), P(16,8), Q(16,8), PT(8), QT(8)
                                                                                          000000
\mathbf{C}
                                                                                          000010
        DO 10 I=1, N
                                                                                          000011
\mathbf{C}
                                                                                          000012
       DO 11 J=1, M
                                                                                          000013
\mathbf{C}
                                                                                          000014
       PT(J) = (0.0, 0.0)
                                                                                          099015
       QT(J) = (0.0, 0.0)
                                                                                          000016
       PT(1) = (1.0, 0.0)
                                                                                          009017
       QT(M) = (1.0, 0.0)
C
                                                                                          000018
                                                                                          000019
       SET TWO-DIMENSIONAL Z MATRIX
                                                                                          000020
č
                                                                                          099021
       DO 11 K=1,M
                                                                                          009022
       ZT(J,K) = Z(I,J,K)
                                                                                          000023
    11 CONTINUE
                                                                                          000024
\mathbf{C}
                                                                                          000025
Ċ
       SET PARAMETER TO PERFORM LU FACTORIZATION AND FORWARD-
                                                                                          000026
C
       BACKWARD SUBSTITUTION FOR UNIT VOLTAGE AT INPUT
                                                                                          000027
Ċ
                                                                                          009028
       IPAR=0
                                                                                          000029
C
                                                                                          000030
       CALL CSOLLU(M, ZT, PT, IFALL, IPAR)
                                                                                          000031
C
                                                                                          009032
       SET PARAMETER TO PERFORM ONLY FORWARD-BACKWARD SUBSTITUTION FOR UNIT VOLTAGE AT OUTPUT
C
                                                                                          000033
\mathbf{c}
                                                                                         000034
\mathbf{C}
                                                                                         000035
       IPAR= 1
                                                                                         000036
\mathbf{C}
                                                                                         000037
       CALL CSOLLU(M, ZT, QT, IFALL, IPAR)
                                                                                         000038
C
                                                                                         000039
       SET TWO DIMENSIONAL SOLUTION VECTORS, EACH COLUMN
                                                                                         000040
C
       CORRESPONDING TO ONE CHANNEL
                                                                                         000041
                                                                                         009042
       DO 12 J=1, M
                                                                                         099043
       P(I,J)=PT(J)
Q(I,J)=QT(J)
                                                                                         009044
                                                                                         000045
   12 CONTINUE
                                                                                         000046
\mathbf{C}
                                                                                         000047
      CONTINUE
                                                                                         009048
       RETURN
                                                                                         000049
       END
                                                                                         000050
C
                                                                                         000051
```

Fig. 1 Listing of the subroutine FILTER.

SUBROUTINE FILABCD

SUBROUTINE FILABCD (N, M, P, Q, PN1, PN2, Y1, GL, YC, Y, YP, YIN, Y3, Y3SQ, TF, H7, H8, H13, H14, PN11, PN12, PN22)

Purpose

This subroutine calculates the equivalent ABCD matrices of filter-junction combinations as seen in the waveguide manifold.

Theory

Using the solution vectors \mathbf{p} and \mathbf{q} evaluated in FILTER, we form the s.c. admittance matrix \mathbf{y} of (9). Matrix \mathbf{y} is then modified to include the input and output transformer ratios \mathbf{n}_1 and \mathbf{n}_2 , respectively. The result is matrix \mathbf{y}' , given by [1]

$$\mathbf{y}' = \begin{bmatrix} n_1^2 \mathbf{y}_{11} & n_1 n_2 \mathbf{y}_{21} \\ n_1 n_2 \mathbf{y}_{21} & n_2^2 \mathbf{y}_{22} \end{bmatrix}$$
(1)

This modification is illustrated schematically by Fig. 1. Next, we find the input admittance Y_{in} of the filter terminated by a load conductance G_L as

$$Y_{in} = y'_{11} - \frac{(y'_{21})^2}{y'_{22} + G_I}.$$
 (2)

For appropriate definitions of variables see Fig. 2. Taking the effect of the impedance inverter into account, we assign as per Fig. 3

$$Y_{in} \leftarrow 1/Y_{in}$$
 (3)

If the junction is modelled by the complex series and shunt admittances [2-3] Y_c and Y_t , respectively, and we denote (see Fig. 4)

$$Y_3 = Y_{in} + Y_c, (4)$$

we can find the complex ABCD matrix of the filter-junction combination, namely T_f , as

$$\mathbf{T}_{f} = \begin{bmatrix} 1 + Y_{1}/Y_{3} & 1/Y_{3} \\ Y_{1}(2 + Y_{1}/Y_{3}) & 1 + Y_{1}/Y_{3} \end{bmatrix}.$$
 (5)

 T_f is designated by the array TF in Fig. 4.

List of Arguments

N is the number of multiplexer channels.

M is the order of the matrix of filter coefficients.

P is the solution to FILTER (6).*

Q is the solution to FILTER (8).*

PN1 is the input transformer ratio (n_1) , as shown in Fig. 1.*

PN2 is the output transformer ratio (n_2) , as shown in Fig. 1.*

Y1 is the shunt junction admittance, as indicated by Fig. 4.*

GL is the terminating load conductance G_L , as illustrated in Fig. 2.*

YC is the series admittance of the junction model, as indicated in Fig. 4.*

Y is the matrix y of FILTER (9), as indicated in Fig. 1.*+

YP is the matrix y' of (1), as indicated in Fig. 1.*+

YIN is the Y input admittance Y_{in}. See Figs. 2 and 3.*

Y3 is the parallel combination of Y_{in} and Y_{c} given by (4), as illustrated in Fig. 4.*

Y3SQ is $(Y_3)^2.*^{\dagger}$

TF is the ABCD matrix of the filter-junction combination, T_f , defined by (5) and

identified in Fig. 4.*+

H7, H8, H13, H14 are intermediate variables defined in the VARIABLES section. They are

easily identified as common variables principally used in (2).

PN11 is $(n_1)^2$.*

PN12 is n₁ n₂.*

PN22 is $(n_2)^2$.*

Related Software

This subroutine is called from SIMUL and SIMGRD2.

References

- [1] M.H. Chen, "Singly terminated pseudo-elliptic function filter", <u>COMSAT Technical</u> Review, vol. 7, 1977, pp. 527-541.
- [2] A.E. Atia, "Computer-aided design of waveguide multiplexers", <u>IEEE Trans.</u>
 <u>Microwave Theory Tech.</u>, vol. MTT-22, 1974, pp. 332-336.
- [3] M.H. Chen, F. Assal and C. Mahle, "A contiguous band multiplexer", <u>COMSAT</u> Technical Review, vol. 6, 1976, pp. 285-306.

Footnote

For an explanation of *, * and * see FEATURES.

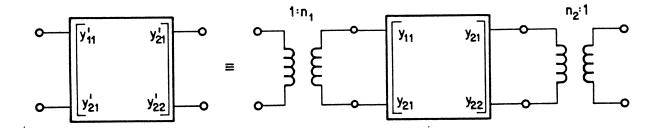


Fig. 1 Modification of the filter equivalent matrix y to include input and output ideal transformers.

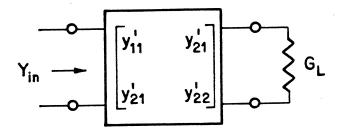
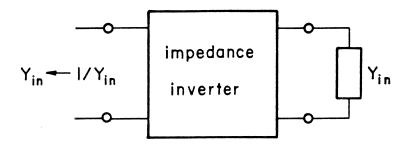


Fig. 2 Input admittance for a filter terminated by conductance G_L after inclusion of n_1 and n_2 as indicated by Fig. 1.



 $Fig. \ 3 \\ \hspace{2cm} Effect on \ Y_{in} \ of \ Fig. \ 2 \ of \ an \ impedance \ inverter.$

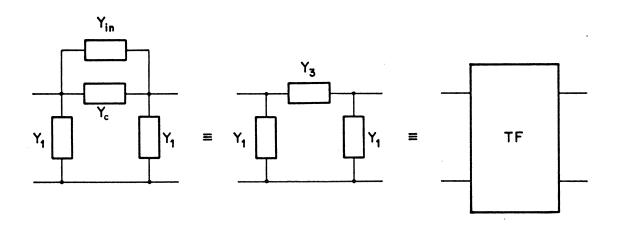


Fig. 4 Filter-junction combination. Y_{in} represents the filter, Y_1 and Y_c the junction admittances. TF represents the ABCD matrix of the combination.

```
C
                                                                                           000052
       SUBROUTINE FILABCD(N, M, P, Q, PN1, PN2, Y1, GL, YC, Y, YP, YIN, Y3,
                                                                                           000053
                               Y3SQ, TF, H7, H8, H13, H14, PN11, PN12, PN22)
                                                                                           000054
\mathbf{c}
                                                                                           009055
       CALCULATION OF EQUIVALENT ABCD MATRICES OF FILTER-
                                                                                           000056
C
       JUNCTION COMBINATIONS AS SEEN IN THE WAVEGUIDE MANIFOLD
                                                                                           000057
C
                                                                                           000058
       COMPLEX Y(16,4), YP(16,4), YIN(16), Y3(16), Y3SQ(16), TF(16,4)
COMPLEX P(16,8), Q(16,8), Y1(16), YC(16)
COMPLEX H7(16), H8(16), H13(16), H14(16)
REAL PN1(16), PN2(16), GL(16)
                                                                                           000059
                                                                                           000060
                                                                                           000061
                                                                                           000062
       REAL PN11(16), PN12(16), PN22(16)
                                                                                           099063
                                                                                           000064
       CALCULATION OF SHORT-CIRCUIT ADMITTANCE MATRIX "Y" OF
                                                                                           000065
       EACH FILTER
                                                                                           000066
C
                                                                                           000067
       DO 13 I=1,N
                                                                                           000068
C
                                                                                           000069
       Y(I,1)=P(I,1)
                                                                                           000070
       Y(1,2)=Q(1,1)
                                                                                           000071
       Y(1,3)=Y(1,2)
                                                                                           000072
                                                                                           000073
       Y(I.4) = Q(I.M)
C
                                                                                           000074
\mathbf{c}
       PREPARATION FOR INCLUSION OF IDEAL TRANSFORMERS
                                                                                           000075
                                                                                           000076
       PN11(I)=PN1(I)*PN1(I)
                                                                                           000077
       PN12(I)=PN1(I)*PN2(I)
                                                                                           000078
       PN22(I)=PN2(I)*PN2(I)
                                                                                           000079
C
                                                                                           000080
       INCLUSION INTO Y MATRIX OF THE INPUT-OUTPUT TRANSFORMERS
C
                                                                                           000081
                                                                                           000082
       YP(I,1)=PN11(I)*Y(I,1)
                                                                                           000083
       YP(I,2) = PN12(I) *Y(I,2)
                                                                                           000084
       YP(1,3)=YP(1,2)
                                                                                           000085
       YP(I,4) = PN22(I) * Y(I,4)
                                                                                           000086
                                                                                           000087
       SAVE COMMON FACTORS FOR USE WITH SENSITIVITY FORMULAS
                                                                                           000088
\mathbf{C}
                                                                                           000089
       H7(I) = YP(I,4) + GL(I)
                                                                                           000090
       H8(I) = YP(I,2) * YP(I,2)
                                                                                           000091
       H13(I) = H8(I) / (H7(I) * H7(I))
                                                                                           000092
       H14(I) = Y1(I) * Y1(I)
                                                                                           000093
\mathbf{c}
                                                                                           000094
       YIN(I) = YP(I, 1) - H8(I) / H7(I)
                                                                                           000095
                                                                                           000096
       USE AN IMPEDANCE INVERTER
                                                                                           000097
C
                                                                                           000098
       YIN(I) = 1.0/YIN(I)
                                                                                           000099
C
                                                                                           009100
       CONNECT THE FILTER TO THE MANIFOLD JUNCTION
                                                                                           000101
C
                                                                                           000102
C
       Y3(I) = YC(I) + YIN(I)
                                                                                           999193
       Y3SQ(1)=Y3(1)*Y3(1)
                                                                                           000104
\mathbf{C}
                                                                                           000105
       TF(I, 1) = 1.0 + Y1(I) / Y3(I)
                                                                                           000106
       TF(I,2) = 1.0/Y3(I)
                                                                                           000107
       TF(1,3)=Y1(1)*TF(1,1)+Y1(1)
                                                                                           000108
       TF(I,4) = 1.0 + Y1(I) / Y3(I)
                                                                                           000109
\mathbf{c}
                                                                                           000110
    13 CONTINUE
                                                                                           000111
       RETURN
                                                                                           000112
                                                                                           000113
\mathbf{C}
                                                                                           000114
```

Fig. 5 Listing of the subroutine FILABCD.

SUBROUTINE MATMUL

SUBROUTINE MATMUL (V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12)

Purpose

This subroutine performs the multiplication of 2×2 complex matrices.

List of Arguments

V1, V2, V3, V4 are elements of the first matrix.

V5, V6, V7, V8 are elements of the second matrix.

V9, V10, V11, V12 are elements of the product matrix.

Related Software

This subroutine is called from SEQUENC, RESPONS, SIMUL, DABCDF2, DRLOSS2, DVOLTA2 and SIMGRD2.

Comments

1) The positions of the elements of the matrices can be shown as

$$\begin{bmatrix} V1 & V2 \\ V3 & V4 \end{bmatrix} \begin{bmatrix} V5 & V6 \\ V7 & V8 \end{bmatrix} = \begin{bmatrix} V9 & V10 \\ V11 & V12 \end{bmatrix}$$
 (1)

The arguments of the subroutine can be elements of one-, two- or threedimensional arrays.

C		000115
_	SUBROUTINE MATMUL(V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12)	000116
C		000117
Č	COMPLEX 2X2 MATRIX MULTIPLICATION	009118
č		000119
-	COMPLEX V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12	000120
	V9=V1*V5+V2*V7	000121
	V10=V1*V6+V2*V8	000122
	V11=V3*V5+V4*V7	000123
	V12=V3*V6+V4*V8	000124
	RETURN	000125
	END	000126
C		000127

Fig. 1 Listing of the subroutine MATMUL.

SUBROUTINE BETAVAL

SUBROUTINE BETAVAL (C1, C2, OMEG, PI2, BETA)

Purpose

This subroutine calculates the rectangular waveguide manifold propagation phase constant $\boldsymbol{\beta}.$

Theory

Denoting the velocity of light in free space by c, where c = 11802.85 inch/µsec, we can calculate the free space wavelength λ and the guide wavelength λ_g in inches, from

$$\lambda = \frac{c}{f},\tag{1}$$

$$\lambda_{g} = \frac{\lambda}{\sqrt{1 - \left(\frac{\lambda}{2a}\right)^{2}}} , \qquad (2)$$

where f is the frequency in MHz and variable a denotes the manifold width in inches. The phase constant β is then given by

$$\beta = \frac{2\pi}{\lambda_g} , \qquad (3)$$

List of Arguments

C1 is the velocity of light c in inch/µsec.

C2 is $4a^2$, where a is the manifold width.

OMEG is the frequency in MHz.

PI2 is 2π.

BETA is β given by (3).

Related Software

This subroutine is called from SIMUL and SIMGRD2.

C		000952
_	SUBROUTINE BETAVAL(C1,C2,OMEG,PI2,BETA)	000953
C		000954
č	WAVEGUIDE MANIFOLD PROPAGATION PHASE CONSTANT IS CALCULATED	000955
č		000956
_	REAL LAM, LAMG	000957
	LAM=C1/OMEG	0 00958
	LAMG=LAM/SQRT(1.0-LAM*LAM/C2)	000959
	BETA=PI2/LAMG	000960
	RETURN	000961
	END	000962
C		000963

Fig. 1 Listing of the subroutine BETAVAL.

SUBROUTINE WGUIDE

SUBROUTINE WGUIDE (N, BETA, WGL, TG, DTG)

Purpose

This subroutine calculates the ABCD matrices of the waveguide manifold spacings and their derivatives w.r.t. the spacings (section lengths).

Theory

The ABCD matrix of a waveguide spacing characterized by the phase constant β and characteristic impedance \boldsymbol{Z}_0 is given by

$$\mathbf{T}_{g} = \begin{bmatrix} \cos \beta \ell & j Z_{0} \sin \beta \ell \\ \frac{j}{Z_{0}} \sin \beta \ell & \cos \beta \ell \end{bmatrix}$$
 (1)

where ℓ denotes the section length. Derivative of T_g w.r.t. ℓ is given by

$$\frac{\partial}{\partial \ell} (\mathbf{T}_{g}) = \begin{bmatrix} -\beta \sin \beta \ell & j Z_{0} \beta \cos \beta \ell \\ \frac{j}{Z_{0}} \beta \cos \beta \ell & -\beta \sin \beta \ell \end{bmatrix}$$
(2)

List of Arguments

N is the number of channels.

BETA is the phase constant β given by BETAVAL (3).

WGL is the section length ℓ .*

TG is the ABCD matrix of the waveguide spacing given by (1).*+

DTG is the derivative of TG w.r.t. section length given by (2).*+

Related Software

This subroutine is called from SIMUL and SIMGRD2.

Comment

In an improved program, calculation of $\partial (T_g)/\partial \ell$ should be avoided when only simulation is required.

Footnote

For an explanation of * and * see FEATURES.

C		000215
	SUBROUTINE WGUIDE(N, BETA, WGL, TG, DTG)	000216
C		000217
C	CALCULATE ABCD MATRICES OF THE WAVEGUIDE SPACINGS AND	000218
C	THEIR DERIVATIVES W.R.T. SPACINGS(SECTION LENGTHS)	000219
C		000220
	COMPLEX TG(16,4),DTG(16,4)	009221
	REAL WGL(16)	000222
C		000223
	CZ= 1.0	000224
	CZ2=CZ*CZ	000225
C		000226
_	DO 77 I=1.N	009227
	TETA=BETA*WGL(I)	000228
C		000229
_	TG(I,1)=CMPLX(COS(TETA),0.0)	000230
	TG(1,2) = CMPLX(0.0,SIN(TETA)*CZ)	000231
	TG(1,3) = TG(1,2) / CZ2	000232
	TG(1,4) = TG(1,1)	000233
C		000234
_	DTG(I.1)=CMPLX(-BETA*SIN(TETA).0.0)	009235
	DTG(I,2)=CMPLX(0.0,COS(TETA)*CZ*BETA)	009236
	DTG(1,3)=DTG(1,2)/CZ2	000237
	DTG(I, 4) = DTG(I, 1)	009238
	77 CONTINUE	000239
C	···doi/11/02	000240
-	RETURN	000241
	END	000242
C		000243
~		000210

Fig. 1 Listing of the subroutine WGUIDE.

SUBROUTINE SEQUENC

SUBROUTINE SEQUENC (N, NP1, T, A)

Purpose

This subroutine calculates the equivalent ABCD matrices of all possible adjacent cascaded sections.

Theory

After evaluation of T_f and T_g for each section (using FILABCD (5) and WGUIDE (1), respectively), we find the ABCD matrix of a section, namely T_f , from (see Fig. 1)

$$T = T_f T_g. (1)$$

Hence, we have T_i , i = 1, 2, ..., N, where N is the number of channels.

The multiplexer structure is a cascade of N sections, where each section is represented by its T matrix. (See Fig. 2).

For a complete simulation and sensitivity analysis of common port return loss and channel insertion losses, we need all the possible products of adjacent section matrices [1] as shown in Fig. 3. We can denote all possible products by $\mathbf{A}_{i,i}$, where

$$\mathbf{A}_{i,j} = \begin{cases} \mathbf{T}_{j-1} & \mathbf{T}_{j-2} & \dots & \mathbf{T}_{i}, & \text{if } j > i \text{ ,} \\ \\ \mathbf{1}_{2 \times 2} & , & \text{if } j = 1 \text{ ,} \\ \\ \text{not defined ,} & \text{if } j < i \text{ ,} \end{cases}$$
 (2a)

for i = 1, 2, ..., N + 1 and j = 1, 2, ..., N + 1.

List of Arguments

N is the number of channels.

NP1 is N+1.

T is the ABCD matrix of a complete section as given in (1).*+

A contains all possible products of adjacent T matrices. It is a three-dimensional array with the first dimension corresponding to the starting section, the second dimension is one more than the ending section and the third dimension identifies the element of the matrix.⁺

Related Software

This subroutine is called from SIMUL and SIMGRD2.

Comments

- If we were only interested in the common port return loss and channel insertion loss responses (simulation only), as we see in the theory for SUBROUTINE RESPONS, a full reverse analysis [1] would be sufficient. The return loss formula needs $\mathbf{A}_{1,N+1}$ and the insertion loss for channel i requires $\mathbf{A}_{1,i}$, which is a by-product of calculations for $\mathbf{A}_{1,N+1}$.
- The derivative of the common port return loss w.r.t. a variable ϕ in section j, requires the evaluation of $\partial A_{1,N+1}/\partial \phi = A_{j+1,N+1} \left(\partial T_j/\partial \phi \right) A_{1,j}$. A full reverse analysis has already given us $A_{1,j}$. Evaluation of $A_{j+1,N+1}$, because of the fact that only j varies, could be accomplished by one full forward analysis. However, in SEQUENC forward analysis is not performed and $A_{j+1,N+1}$ is obtained as the by-product of a more complicated computational scheme required by channel insertion loss sensitivity analysis.
- The derivative of the insertion loss for channel i w.r.t. a variable φ in section j, where j < i, requires the evaluation of $\partial A_{1,i}/\partial \varphi = A_{j+1,i}$ ($\partial T_j/\partial \varphi$) $A_{1,j}$. Evaluation of $A_{j+1,i}$, where both i and j vary, is the reason for the substantial computational effort in SEQUENC, which is considerably more than just a forward and reverse analysis.

References

- [1] L.S. Lasdon and A.D. Waren, "Optimal design of filters with bounded, lossy elements", IEEE Trans Circuit Theory, vol. CT-13, 1966, pp. 175-187.
- [2] J.W. Bandler, M.R.M. Rizk and H.L. Abdel-Malek, "New results in network simulation, sensitivity and tolerance analysis for cascaded structures", <u>IEEE Trans. Microwave Theory Tech.</u>, vol. MTT-26, 1978, pp. 963-972.

Footnote

For an explanation of * and + see FEATURES.

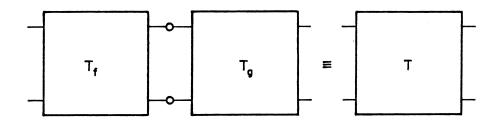


Fig. 1 Cascade combination of a filter-junction and waveguide spacing forming a complete section.

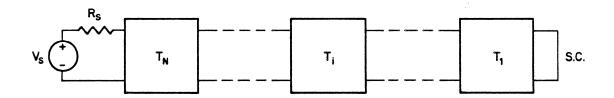


Fig. 2 Multiplexer structure after reduction to a simple cascaded network using the T elements defined in Fig. 1.

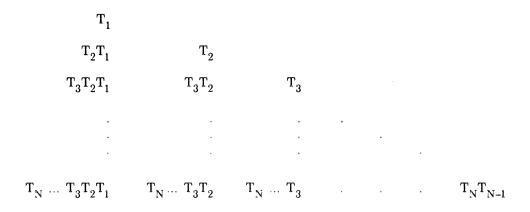


Fig. 3 All the possible products of adjacent section matrices as defined by (2).

```
000128
C
                                                                                                                 000129
         SUBROUTINE SEQUENC(N, NP1, T, A)
                                                                                                                 000130
C
        CALCULATE THE EQUIVALENT ABCD MATRICES OF ALL POSSIBLE ADJACENT CASCADED SECTIONS AND STORE THEM IN THE A MATRICES. MATRIX A(I,J,.) INDICATES CALCULATIONS FROM REFERENCE PLANE I TO REFERENCE PLANE J, WHERE J>I.

T IS THE ABCD MATRIX OF A SECTION(FILTER-JUNCTION COMBINATION
                                                                                                                 000131
0000000
                                                                                                                 000132
                                                                                                                 000133
                                                                                                                 000134
                                                                                                                 000135
                                                                                                                 000136
         AND WAVEGUIDE SPACING)
                                                                                                                 000137
                                                                                                                 000138
         COMPLEX T(16,4),A(17,17,4)
                                                                                                                 000139
C
         INITIALIZE UNIT MATRICES
                                                                                                                 000140
C
                                                                                                                 000141
                                                                                                                 000142
         DO 16 I=1, NP1
                                                                                                                 000143
C
                                                                                                                 000144
         A(I,I,1) = CMPLX(1.0,0.0)
                                                                                                                 000145
         A(1,1,2) = CMPLX(0.0,0.0)
                                                                                                                 000146
         A(I,I,3)=A(I,I,2)
                                                                                                                 000147
         A(I,I,4) = A(I,I,1)
                                                                                                                 009148
C
     16 CONTINUE
                                                                                                                 000149
                                                                                                                 000150
C
         DO 17 I=1,N
                                                                                                                 000151
         IP1=I+1
                                                                                                                 000152
                                                                                                                 000153
C
                                                                                                                 000154
         DO 18 J= IP1, NP1
                                                                                                                 000155
         JM1=J-1
                                                                                                                 000156
\mathbf{c}
         CALL MATMUL(T(JM1,1),T(JM1,2);T(JM1,3),T(JM1,4),A(I,JM1,1),
A(I,JM1,2),A(I,JM1,3),A(I,JM1,4),A(I,J,1),
A(I,J,2),A(I,J,3),A(I,J,4))
                                                                                                                 000157
                                                                                                                 000158
                                                                                                                 000159
                                                                                                                 000160
C
     18 CONTINUE
                                                                                                                 000161
                                                                                                                 000162
        CONTINUE
                                                                                                                 000163
         RETURN
                                                                                                                 000164
         END
                                                                                                                 000165
C
```

Fig. 4 Listing of the subroutine SEQUENC.

SUBROUTINE RESPONS

SUBROUTINE RESPONS (N, NP1, RS, ZIN, RLOSS, VL, A, H23, H1, RO, RCOEFF, YC, YP, TG, Y1, VS, H2, H3, H4, H5, H6, H7, H9, H10)

Purpose

This subroutine calculates the common port return loss and output voltage for each channel.

Theory

After evaluation of the **A** matrices in SUBROUTINE SEQUENC, Fig. 2 of SEQUENC can be further simplified. The result is shown in Fig. 1. Denoting the input impedance by Z_{in} , the reflection coefficient by ρ and the common port return loss by L_R , we have [1, 2]

$$Z_{in} = \frac{e_1^T A_{1,N+1} e_2}{e_2^T A_{1,N+1} e_2},$$
(1)

$$\rho = \frac{Z_{in} - R_S}{Z_{in} + R_S} , \qquad (2)$$

and

$$L_{R} = -20\log|\rho|, \qquad (3)$$

where $\mathbf{e}_1 = [1 \ 0]^T$, $\mathbf{e}_2 = [0 \ 1]^T$ and \mathbf{R}_S is the source resistance.

To calculate the channel output voltages, direct application of the formulas presented by Bandler, Rizk and Abdel-Malek [1], specifically their equation (21), for the ith channel, gives

$$V_{L}^{i} = \frac{\mathbf{e}_{2}^{T} \begin{bmatrix} 1 & 0 \\ Y_{1}^{i} & 1 \end{bmatrix} \mathbf{T}_{g}^{i} \mathbf{A}_{1,i} \mathbf{e}_{2} V_{S}}{\left(\mathbf{e}_{2}^{T} \begin{bmatrix} 1 & 0 \\ Y_{c}^{i} & 1 \end{bmatrix} \begin{bmatrix} 0 & j \\ j & 0 \end{bmatrix} \mathbf{T}_{ff}^{i} \begin{bmatrix} 1 \\ G_{L}^{i} \end{bmatrix} \right) \left(\mathbf{e}_{1}^{T} \begin{bmatrix} 1 & R_{S} \\ 0 & 1 \end{bmatrix} \mathbf{A}_{1,N+1} \mathbf{e}_{2}^{i} \right)},$$
(4)

(see Fig. 2), where V_S is the source voltage and T_{ff} is the ABCD matrix for an unterminated filter including input and output transformers. Using y' from (1) of FILABCD and converting the s.c. admittance matrix to an ABCD matrix, T_{ff} is actually evaluated as [2]

$$\mathbf{T}_{ff} = \begin{bmatrix} -y_{22}/y_{21} & -1/y_{21} \\ y_{21} - \frac{y_{11}}{y_{21}} & -y_{11}/y_{21} \\ y_{21} - \frac{y_{11}}{y_{21}} & -y_{11}/y_{21} \end{bmatrix},$$
 (5)

Using (5) and some simplifications, we get

$$\mathbf{e}_{2}^{T} \begin{bmatrix} 1 & 0 \\ Y_{c} & 1 \end{bmatrix} \begin{bmatrix} 0 & j \\ j & 0 \end{bmatrix} \mathbf{T}_{ff} \begin{bmatrix} 1 \\ G_{L} \end{bmatrix} = j \begin{bmatrix} Y_{c} y_{21}^{'} - \frac{(y_{22}^{'} + G_{L})(1 + Y_{c} y_{11}^{'})}{y_{21}^{'}} \end{bmatrix},$$
 (6)

and V_L i becomes

$$V_{L}^{i} = \frac{j[Y_{1} \quad 1] T_{g}^{i} A_{1,i} e_{2} V_{S}}{\left(\frac{\left(y_{22}^{'} + G_{L}\right)\left(1 + Y_{c} y_{11}^{'}\right)}{y_{21}^{'}} - Y_{c} y_{21}^{'}\right) [1 \quad R_{S}] A_{1,N+1} e_{2}}$$
(7)

Note that we have omitted the superscript i needed for y_{11} , y_{21} , y_{22} , Y_c , G_L and Y_1 , for simplicity.

List of Arguments

N is the number of channels.

NP1 is N+1.

RS is the source resistance in ohms.

ZIN is the complex input impedance at the common port.

RLOSS is the return loss in dB.

VL is the channel output voltage.*

A is as defined in SEQUENC.

H23, H1 are intermediate variables defined in the VARIABLES section.

RO is the modulus of the reflection coefficient, $|\rho|$.

RCOEFF is the complex reflection coefficient ρ .

YC is as defined in FILABCD.

YP is as defined in FILABCD.

TG is as defined in WGUIDE.

Y1 is as defined in FILABCD.

VS is the source voltage.

H2, H3, H4, H5, H6, H7, H9 and H10 are intermediate variables defined in the VARIABLES section.[†]

Related Software

This subroutine is called from SIMUL and SIMGRD2.

References

- [1] J.W. Bandler, M.R.M. Rizk and H.L. Abdel-Malek, "New results in network simulation, sensitivity and tolerance analysis for cascaded structures", <u>IEEE Trans. Microwave Theory Tech.</u>, vol. MTT-26, 1978, pp. 963-972.
- [2] G.L. Matthaei, L. Young and E.M.T. Jones, <u>Microwave Filters, Impedance Matching Networks and Coupling Structures</u>. New York: McGraw-Hill, 1964, Chap. 2.

Footnote

For an explanation of * and † see FEATURES.

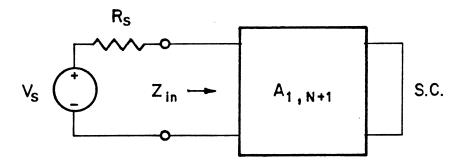


Fig. 1 Simplified multiplexer structure for the calculation of return loss.

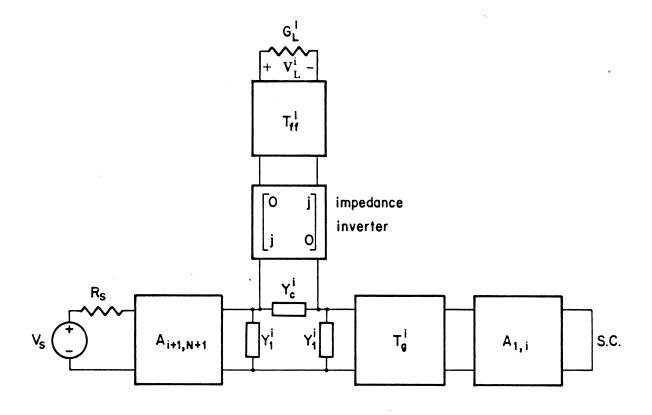


Fig. 2 Simplified multiplexer structure for the calculation of channel output voltage.

```
000166
C
       SUBROUTINE RESPONS(N, NP1, RS, ZIN, RLOSS, VL, A, H23, H1, RO, RCOEFF,
                                                                                         000167
                           YC, YP, TG, Y1, VS, H2, H3, H4, H5, H6, H7, H9, H10)
                                                                                         000168
                                                                                         000169
C
       CALCULATE COMMON PORT RETURN LOSS AND OUTPUT VOLTAGE
                                                                                         000170
C
                                                                                         000171
C
       OF EACH CHANNEL
                                                                                         000172
C
       COMPLEX VL(16), A(17,17,4), HMX(4)
COMPLEX H2(16), H3(16), H4(16), H5(16), H6(16), H7(16), H9(16), H10(16)
COMPLEX YC(16), YP(16,4), TG(16,4), Y1(16)
                                                                                         000173
                                                                                         000174
                                                                                         000175
                                                                                         000176
       COMPLEX RCOEFF, ZIN, H22, H23, H1, JPLX
                                                                                         000177
       JPLX=CMPLX(0.0,1.0)
                                                                                         000178
\mathbf{C}
       CALCULATION OF INPUT IMPEDANCE USING ABCD MATRIX FROM
                                                                                         000179
C
       REFERENCE PLANE 1 (SHORT CIRCUIT) TO REFERENCE PLANE N+1
                                                                                         000180
C
                                                                                         000181
       ZIN=A(1,NP1,2)/A(1,NP1,4)
                                                                                         000182
                                                                                         000183
       H22=(ZIN+RS)*(ZIN+RS)
                                                                                         000184
       H23=2.0*RS/H22
                                                                                         000185
       RCOEFF=(ZIN-RS)/(ZIN+RS)
                                                                                         000186
       RO=CABS(RCOEFF)
                                                                                         000187
       RLOSS=-20.0*ALOG10(RO)
                                                                                         000188
\mathbf{C}
       H1=A(1,NP1,2)+RS*A(1,NP1,4)
                                                                                         000189
                                                                                         000190
\mathbf{C}
                                                                                         000191
       DO 19 I=1,N
                                                                                         000192
C
                                                                                         000193
       H9(I) = 1.0 + YC(I) * YP(I, 1)
       H10(I)=H7(I)*H9(I)
                                                                                         000194
                                                                                         000195
       H2(I) = H10(I) / YP(I,2) - YC(I) * YP(I,2)
                                                                                         000196
\mathbf{c}
       CALCULATE ABCD MATRICES FROM THE SHORT CIRCUIT REFERENCE
                                                                                         000197
\mathbf{c}
       PLANE TO THE REFERENCE PLANE I
                                                                                         000198
C
                                                                                         000199
       CALL MATMUL(TG(I,1),TG(I,2),TG(I,3),TG(I,4),A(1,I,1),A(1,I,2),
                                                                                         000200
                  A(1,1,3),A(1,1,4),HMX(1),HMX(2),HMX(3),HMX(4))
                                                                                         000201
                                                                                         000202
C
                                                                                         000203
       H3(I) = VS*(HMX(4) + Y1(I)*HMX(2))
       H4(I)=H2(I)*H1
H5(I)=H4(I)*H4(I)
                                                                                         000204
                                                                                         000205
       H6(I)=H3(I)*H2(I)
                                                                                         000206
                                                                                         009207
                                                                                         000208
       CALCULATE OUTPUT VOLTAGES OF CHANNELS
                                                                                         009209
                                                                                         000210
       VL(I)=JPLX*H3(I)/H4(I)
       CONTINUE
                                                                                         000211
       RETURN
                                                                                         000212
                                                                                         000213
C
                                                                                         000214
```

Fig. 3 Listing of the subroutine RESPONS.

SUBROUTINE INSOUT

SUBROUTINE INSOUT (N, VL, INLOSS)

Purpose

This subroutine calculates the channel insertion loss using the channel output voltage.

Theory

The channel insertion loss is given by [1]

$$I_L = -20 \log |V_L| -20 \log (R_S G_L + 1),$$
 (1)

where V_L is as defined in (7) of RESPONS. For simplicity, we have again omitted the superscript i for I_L , V_L and G_L . Assuming unity source and load resistances, we have

$$I_{I} = -20 \log(2|V_{I}|)$$
 (2)

List of Arguments

N is the number of channels.

VL is the complex channel output voltage V_L.*

INLOSS is the channel insertion loss I_L in dB.*

Related Software

This subroutine is called from SIMUL.

References

[1] G.L. Matthaei, L. Young and E.M.T. Jones, <u>Microwave Filters, Impedance Matching Networks and Coupling Structures</u>. New York: McGraw-Hill, 1964, Chap. 2.

Footnote

For an explanation of * see FEATURES.

C		000964
•	SUBROUTINE INSOUT(N.VL, INLOSS)	000965
C		000966
č	CHANNEL INSERTION LOSS IS CALCULATED	000967
č		0 0096 B
•	COMPLEX VL(16)	000969
	REAL INLOSS(16)	000970
C	111111111111111111111111111111111111111	000971
č	THIS SUBROUTINE IS WRITTEN FOR VS=1.0, RS=1.0, GL(I)=1.0	000972
č		000973
·	DO 10 I=1.N	000974
	VABS=CABS(VL(I))	000975
	INLOSS(I) = -20.0*ALOG10(2.0*VABS)	000976
	10 CONTINUE	000977
	RETURN	000978
	END	000979
C	END.	000980

Fig. 1 Listing of the subroutine INSOUT.

SUBROUTINE PHASE

SUBROUTINE PHASE (N, VL, ANGLE)

Purpose

This subroutine calculates the phase of the complex channel output voltage.

Theory

Given the complex channel output voltage \boldsymbol{V}_L , its phase is calculated as

$$\angle V_L = Im(V_L)/Re(V_L)$$
.

List of Arguments

N is the number of channels.

VL is the complex channel output voltage.*

PHASE is the phase of V_L .

Related Software

This subroutine is called from SIMUL.

Footnote

For an explanation of * see FEATURES.

C	The state of the s	001055 001056
C	SUBROUTINE PHASE(N, VL, ANGLE)	001057
č	GIVEN THE COMPLEX CHANNEL OUTPUT VOLTAGE CALCULATE THE	001058
č	CORRESPONDING PHASE	001059
č		001060
~	COMPLEX VL(16)	001061
	REAL ANGLE(16)	001062
C		001063
٠	DO 10 I=1,N	001064
	HRE=REAL(VL(I))	001065
	HIM-AIMAG(VL(I))	001066
	ANGLE(I)=ATAN2(HIM, HRE)	001067
	10 CONTINUE	001068
	RETURN	001069
	END	001070

Fig. 1 Listing of the subroutine PHASE.

SUBROUTINE CSOLLU

SUBROUTINE CSOLLU (M, A, B, IFALL, IPAR)

Purpose

This subroutine performs LU factorization, forward and backward substitutions in the complex mode.

Theory

The subroutines use Crout's algorithm for LU factorization. It has the capability of forward and backward substitution with or without LU factorization.

List of Arguments

M is the order of the matrix.

A is the matrix of coefficients on entry. It contains the LU factors on exit.

B is the RHS vector on entry. It contains the solution vector on exit.

IFALL is a flag set to -1 if, due to a zero on the diagonal, an indefinite value occurs in

CSOLLU.

IPAR is a flag to determine whether LU factorization together with FBS, or only

FBS is to be performed. IPAR = 1 for FBS only, and IPAR \neq 1 for both LU

and FBS.

Related Software

This subroutine is called from FILTER.

```
000244
\mathbf{c}
                                                                                   000245
      SUBROUTINE CSOLLU(M, A, B, IFALL, IPAR)
                                                                                   009246
C
      PERFORM LU FACTORIZATION, FORWARD AND BACKWARD SUBSTITUTION
                                                                                   000247
      IN THE COMPLEX MODE
                                                                                   009248
C
                                                                                   000249
C
      COMPLEX A(8,8),B(8),ZZ
                                                                                   000250
                                                                                   000251
C
      CROUT'S ALGORITHM FOR LU FACTORIZATION
                                                                                   000252
\mathbf{C}
                                                                                   000253
                                                                                   009254
      IFALL=0
                                                                                   000255
      M2=M-1
      M1=M+1
                                                                                   000256
                                                                                   000257
      IF( IPAR. EQ. 1) GO TO 290
                                                                                   000258
                                                                                   000259
Ċ
      BEGIN FACTORIZATION
                                                                                   000260
                                                                                   000261
      DO 82 II=1,M2
                                                                                   000262
      ZZ=A(II,II)
                                                                                   000263
      IF(ZZ.EQ.(0.0,0.0))GO TO 100
                                                                                   009264
      MM= I I+1
                                                                                   000265
      DO 82 J=MM, M
                                                                                   000266
      A(II,J) = A(II,J)/ZZ
   DO 80 K=MM,M
80 A(K,J)=A(K,J)-A(K,II)*A(II,J)
                                                                                   000267
                                                                                   000268
   82 CONTINUE
                                                                                   000269
                                                                                   000270
č
      FORWARD SUBSTITUTION
                                                                                   000271
C
                                                                                   000272
  290 CONTINUE
                                                                                   000273
      IF(A(1,1).EQ.(0.0,0.0))GO TO 100
                                                                                   009274
                                                                                   000275
      B(1) = B(1) / A(1,1)
      DO 88 II=2,M
ZZ=A(II,II)
                                                                                   000276
                                                                                   000277
       IF(ZZ.EQ.(0.0,0.0))GO TO 100 '
                                                                                   000278
                                                                                   000279
      IM= II-1
                                                                                   000280
      DO 86 K=1, IM
   86 B(II)=B(II)-A(II,K)*B(K)
                                                                                   000281
      B(II) = B(II)/ZZ
                                                                                   000282
   88 CONTINUE
                                                                                   000283
                                                                                   000284
                                                                                   000285
      BACKWARD SUBSTITUTION
C
                                                                                   000286
                                                                                   000287
      DO 92 L=2, M
II=M1-L
                                                                                   009288
                                                                                   000289
      IP= II+1
                                                                                   000290
      DO 90 K= IP, M
   90 B(II)=B(II)-A(II,K)*B(K)
                                                                                   000291
   92 CONTINUE
                                                                                   000292
                                                                                   000293
      GO TO 120
                                                                                   000294
  100 IFALL=-1
                                                                                   000295
      WRITE 200
  200 FORMAT(/"INDEFINITE VALUE IN CSOLLU DUE TO ZERO ON THE DIAGONAL")
                                                                                   000296
  120 CONTINUE
                                                                                   000297
                                                                                   000298
                                                                                   000299
\mathbf{c}
                                                                                   000300
```

Fig. 1 Listing of the subroutine CSOLLU.

SUBROUTINE CONST1

SUBROUTINE CONST1 (WIDTH)

COMMON/BLK4/CBR, FCUT

Purpose

This subroutine calculates the rectangular waveguide manifold cut-off frequency.

Theory

The cut-off frequency in MHz is given by

$$f_{cut} = \frac{c}{2a} , \qquad (1)$$

where c=11802.85 inch/µsec is the velocity of light in free space and variable a is the manifold width in inches.

<u>List of Arguments and COMMON Blocks</u>

WIDTH is the manifold width a.

CBR is the velocity of light c.

FCUT is the cut-off frequency f_{cut} .

Related Software

This subroutine is called from the main program MXSOS2 if the junction susceptance option is selected.

\mathbf{C}	000981
SUBROUTINE CONSTI(WIDTH)	000982
C	000983
C WAVEGUIDE MANIFOLD CUTOFF FREQUENCY IS CALCULATED	000984
C	000985
COMMON/BLK4/CBR, FCUT	000986
CBR= 11802.85	000987
FCUT=CBR/(2.0*WIDTH)	000988
RETURN	000989
END	000990
C	000991

Fig. 1 Listing of the subroutine CONST1.

SUBROUTINE DISPAT

SUBROUTINE DISPAT (N, WO, BW, QO)

COMMON/BLK5/DISP

Purpose

This subroutine estimates the filter dissipation using the unloaded Q, bandwidth parameter and center frequency of the filter.

Theory

The filter dissipation factor d, which is added to the diagonal elements of the impedance matrix for a lossy filter, is calculated as

$$d = \frac{f_0}{\Delta f Q_0} , \qquad (1)$$

where \boldsymbol{f}_0 is the centre frequency, $\Delta \boldsymbol{f}$ is the bandwidth parameter and \boldsymbol{Q}_0 is the unloaded \boldsymbol{Q}

List of Arguments and COMMON Blocks

N is the number of channels.

WO is the centre frequency f_0 .*

BW is the bandwidth Δf .*

QO is the unloaded Q.*

DISP is the dissipation d.*

Related Software

This subroutine is called from the main program MXSOS2 if the dissipation option is selected.

Footnote

For an explanation of * see FEATURES.

C		000992
_	SUBROUTINE DISPAT(N, WO, BW, QO)	000993
C	, , ,	000994
č	FILTER DISSIPATION IS CALCULATED USING UNLOADED Q. B	ANDWIDTHS 000995
č	AND CENTER FREQUENCIES	000996
č		000997
•	REAL WO(16), BW(16), DISP(16), QO(16)	000998
	COMMON/BLK5/DISP	000999
C		001000
•	DO 10 I=1,N	001001
	DISP(I) = WO(I) / (BW(I) * QO(I))	001002
	10 CONTINUE	001003
	RETURN	001004
	END	001005
C		001006

Fig. 1 Listing of the subroutine DISPAT

DISPER-1

SUBROUTINE DISPER

SUBROUTINE DISPER (N, WO, BW, DIA)

COMMON/BLK6/FCNST, LAMRES, LAMDEL

Purpose

This subroutine calculates the filter constant (square of the cut-off frequency of the filter), circular guide wavelength corresponding to the filter resonant frequency and the difference in filter guide wavelengths corresponding to the band edges.

Theory

The cut-off frequency for the circular waveguide is calculated as

$$ff_{cut} = \frac{c}{1.7063 d_f}, \qquad (1)$$

where c=11802.85 inch/µsec is the velocity of light in free space and d_f is the filter diameter in inches. We define filter constant f_{cst} as

$$f_{cst} \stackrel{\Delta}{=} (ff_{cut})^2$$
. (2)

Using f_{cst} , we can find the guide wavelengths corresponding to the band edges, in the following way:

$$f_{\ell} = f_0 - \frac{\Delta f}{2}$$
, $f_h = f_0 + \frac{\Delta f}{2}$ (3)

and

$$\lambda_{g\ell} = \frac{c}{\sqrt{(f_{\ell})^2 - f_{cst}}}, \qquad \lambda_{gh} = \frac{c}{\sqrt{(f_{h})^2 - f_{cst}}}, \qquad (4)$$

where f_0 is the centre frequency, Δf is the bandwidth, f_ℓ and f_h are the band edges and $\lambda_{g\ell}$ and λ_{gh} are their corresponding guide wavelengths. The guide wavelength corresponding to the filter resonant frequency is defined as

$$\lambda_{\text{res}} \stackrel{\triangle}{=} (\lambda_{\text{g}\ell} + \lambda_{\text{gh}})/2 \tag{5}$$

and we also define

$$\lambda_{\Delta} \stackrel{\triangle}{=} \lambda_{g\ell} - \lambda_{gh} . \tag{6}$$

List of Arguments and COMMON Blocks

N is the number of channels.

WO is the centre frequency f_0 .*

BW is the bandwidth Δf .*

DIA is the filter diameter d_f.*

FCNST is the filter constant f_{est} of (2).

LAMRES $\;\;$ is the guide wavelength corresponding to the filter resonant frequency λ_{res} of

(5).*

LAMDEL is the difference in filter guide wavelengths corresponding to the band edges

 λ_{Δ} of (6).*

Related Software

This subroutine is called from the main program MXSOS2 if the option of dispersion is requested.

Footnote

For an explanation of * see FEATURES.

C			001007
		SUBROUTINE DISPER(N, WO, BW, DIA)	001008
C			0 01009
Ċ		CALCULATES THE DISPERSIVE EFFECTS IN EACH FILTER	001010
Č		THE OUTPUT FROM THIS SUBROUTINE INCLUDES FILTER GUIDE	001011
Č		WAVELENGTH CORRESPONDING TO THE FILTER RESONANT FREQUENCY	001012
č		AND THE DIFFERENCE IN FILTER GUIDE WAVELENGTHS CORRESPONDING	001013
č		TO THE BAND EDGES.	001014
č		TO THE BRICE LEGISLY	001015
•		REAL WO(16), BW(16), DIA(16), FCNST(16), LAMRES(16), LAMDEL(16)	001016
		REAL LAMI.OG. LAMHIG	001017
		COMMON/BLK6/FCNST, LAMRES, LAMDEL	001011
		CB= 11802.85	001019
		CD1A=CB*CB/(1.7063*1.7063)	001019
~		CDTA-CD*CD/(1.7003*1.7003)	001020
C		DO 10 T-1 N	001021
		DO 10 I=1,N	
		FCNST(I)=CDIA/(DIA(I)*DIA(I))	001023
C			001024
		FLO=WO(1)-BW(1)/2.0	001025
		FHI=FLO+BW(I)	001026
C			001027
		LAMLOG=CB/(SQRT(FLO*FLO-FCNST(I)))	001028
		LAMHIC=CB/(SQRT(FHI*FHI-FCNST(I)))	001029
C			001030
		LAMRES(I)=(LAMLOG+LAMHIG)/2.0	001031
		LAMDEL(I)=LAMLOG-LAMHIG	001032
C			001033
•	10	CONTINUE	001034
	10	RETURN	001035
		END	001036
C		END .	001037
U			001001

Fig. 1 Listing of the subroutine DISPER.

SUBROUTINE SIMUL

SUBROUTINE SIMUL (OMEG, N, M, ICOUNT, IFLAGJS, IFLAGDP, IDISPER, RLOSS, INLOSS, ANGLE)

COMMON/BLK1/WO, BW, PN1, PN2, GL, VS, RS, PI2, WIDTH, NP1

COMMON/BLK2/CM, WGL

COMMON/BLK4/CBR, FCUT

COMMON/BLK6/FCNST, LAMRES, LAMDEL

COMMON/BLK7/CEL

Purpose

This subroutine sets up the complex **Z** matrix according to the options of dissipation and dispersion, calculates the nonideal junction susceptances if that option is selected and calls all subroutines required for simulation only.

Theory

If neither dissipation nor dispersion options is selected, the Z matrix is defined as [1]

$$\mathbf{Z} \stackrel{\Delta}{=} \mathbf{j}(\mathbf{s}\mathbf{1} + \mathbf{M}) \,, \tag{1}$$

where M is the coupling matrix, 1 is the unit matrix of corresponding dimensions and

$$s \stackrel{\Delta}{=} \frac{\omega_0}{\Delta \omega} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) = \frac{f_0}{\Delta f} \left(\frac{f}{f_0} - \frac{f_0}{f} \right), \tag{2}$$

where $f_0(\omega_0)$ is the centre frequency, $\Delta f(\Delta\omega)$ is the bandwidth parameter and $f(\omega)$ is the frequency of operation.

If the dispersion option is selected, we use f_{cst} , λ_{res} and λ_{Δ} as calculated in DISPER to evaluate

$$\lambda_{\rm f} = \frac{\rm c}{\sqrt{\rm f^2 - f_{\rm est}}} \quad , \tag{3}$$

SIMUL-2

$$\lambda_{\rm r} = \frac{\lambda_{\rm f}}{\lambda_{\rm res}} \tag{4}$$

and

$$\lambda_{x} = \frac{2(\lambda_{res} - \lambda_{f})}{\lambda_{\Delta}} . \tag{5}$$

The (ℓ, k) th element of impedance matrix $\overline{\mathbf{Z}}$ is calculated as

$$\overline{Z}_{\ell k} = j[M_{\ell k}(\lambda_r)^{C_{\ell k}} + c_d], \qquad (6)$$

where

$$c_{d} = \begin{cases} \lambda_{x} , & \text{if } \ell = k \\ 0 , & \text{if } \ell \neq k \end{cases}$$
 (7)

and ${\bf C}$ is a matrix whose elements determine the type of coupling in the following way:

$$\mathbf{C}_{\ell\mathbf{k}} = \begin{cases} 1 &, & \text{if } \mathbf{M}_{\ell\mathbf{k}} \text{ is screw coupled.} \end{cases} \tag{8a}$$

$$\mathbf{C}_{\ell\mathbf{k}} = \begin{cases} -1 &, & \text{if } \mathbf{M}_{\ell\mathbf{k}} \text{ is iris coupled.} \end{cases} \tag{8b}$$

$$0 &, & \text{if } \mathbf{M}_{\ell\mathbf{k}} = 0 \text{, or } \ell = \mathbf{k}. \tag{8c}$$

If the dissipation option is included, both matrix \mathbf{Z} of (1) (no dispersion) and matrix $\overline{\mathbf{Z}}$ of (6) (dispersion included) should be updated in the following way:

$$\mathbf{Z} \leftarrow \mathbf{Z} + d\mathbf{1}$$
 and $\mathbf{\overline{Z}} \leftarrow \mathbf{\overline{Z}} + d\mathbf{1}$, (9)

where d is defined in DISPAT and 1 is the unit matrix of corresponding dimensions.

In FILABCD, we named the junction series and shunt admittances as Y_c and Y_1 , respectively. See Fig. 4 of FILABCD. In MXSOS2, YC is always assumed to be zero [2], however, Y_1 is zero only if the junction susceptance option is not selected. By selecting nonideal junction susceptance, Y_1 is calculated as [3]

$$Y_{1} = \frac{-j f_{cut}}{\left(20 \left(\frac{c}{f}\right)^{2} - 1\right) \sqrt{f^{2} - (f_{cut})^{2}}},$$
(10)

where f_{cut} is defined in CONST1 (1), c is the velocity of light and f is the frequency of operation.

List of Arguments and COMMON Blocks

The definition of the arguments and common blocks can be found in the main program MXSOS2 as well as in CONST1, DISPAT and DISPER.

Related Software

This subroutine is called from the main program MXSOS2 if the simulation option is selected.

References

- [1] A.E. Atia and A.E. Williams, "New types of waveguide bandpass filters for satellite applications", <u>COMSAT Technical Review</u>, vol. 1, 1971, pp. 21-43.
- [2] R. Tong and C.M. Kudsia, ComDev Ltd., Cambridge, Ontario, Canada, private discussions 1983, 1984.
- [3] M.H. Chen, F. Assal and C. Mahle, "A contiguous band multiplexer", <u>COMSAT Technical Review</u>, vol. 6, 1976, pp. 285-306.

```
000812
C
       SUBROUTINE SIMUL(OMEG, N, M, ICOUNT, IFLAGJS, IFLAGDP, IDISPER,
                                                                                               000813
                            RLOSS, INLOSS, ANGLE)
                                                                                               000814
                                                                                               000815
C
       THIS SUBROUTINE CALLS ALL SUBROUTINES NECESSARY FOR RESPONSE
                                                                                               000816
                                                                                               000817
\mathbf{c}
       CALCULATIONS ONLY
                                                                                               000818
C
       COMPLEX Z(16,8,8),P(16,8),Q(16,8)
COMPLEX Y(16,4),YP(16,4),YIN(16),Y1(16),Y3(16),YC(16)
COMPLEX TF(16,4),TG(16,4),T(16,4),A(17,17,4),Y3SQ(16)
                                                                                               009819
                                                                                               000820
                                                                                               000821
                                                                                               009822
        COMPLEX DTG(16,4)
       COMPLEX H2(16), H3(16), H4(16), H5(16), H6(16), H7(16), HB(16)
COMPLEX H9(16), H10(16), H13(16), H14(16)
                                                                                               000823
                                                                                               000824
                                                                                               000825
       COMPLEX VL(16)
COMPLEX H1, H23, ZIN, RCOEFF
                                                                                               000826
                                                                                               000827
       COMPLEX S,SD
       REAL WO(16), BW(16)
                                                                                               000828
       REAL CM(16,8,8), PN1(16), PN2(16), PN11(16), PN12(16)
                                                                                               000829
       REAL PN22(16),GL(16),WGL(16),INLOSS(16),ANGLE(16)
REAL DISP(16),LAMR(16)
                                                                                               000830
                                                                                               000831
                                                                                               000832
       REAL FCNST(16), LAMRES(16), LAMDEL(16), LAMFIL, LREAC
                                                                                               000833
        INTEGER CEL(16,8,8)
                                                                                               000834
C
       COMMON/BLK1/WO, BW, PN1, PN2, GL, VS, RS, P12, WIDTH, NP1 COMMON/BLK2/CM, WGL
                                                                                               000835
                                                                                               000836
       COMMON/BLK4/CBR, FCUT
                                                                                               000837
       COMMON/BLK5/DISP
                                                                                               000838
                                                                                               000839
       COMMON/BLK6/FCNST, LAMRES, LAMDEL
                                                                                               000840
       COMMON/BLK7/CEL
                                                                                               000841
\mathbf{c}
                                                                                               000842
       IF(ICOUNT.NE.1)GO TO 5
                                                                                               000843
\mathbf{c}
       DO 100 I=1, N
                                                                                               000844
       DO 100 J=1,M
DO 100 KK=1,J
                                                                                               009845
                                                                                               000846
                                                                                               000847
       CM(I,J,KK) = CM(I,KK,J)
                                                                                               000848
  100 CONTINUE
                                                                                               000849
\mathbf{C}
       DO 99 I=1, N
DO 99 J=1, M
DO 99 K=1, M
                                                                                               009850
                                                                                               000851
                                                                                               000852
       Z(I,J,K) = CMPLX(0.0,CM(I,J,K))
                                                                                               000853
                                                                                               000854
   99 CONTINUE
                                                                                               000855
C
                                                                                               000856
       C1=11802.85
C2=4.0*WIDTH*WIDTH
                                                                                               000857
C
                                                                                               009858
                                                                                               000859
     5 CONTINUE
                                                                                               000860
\mathbf{C}
                                                                                               000861
       IF(IDISPER.NE.1)GO TO 500
                                                                                               000862
\mathbf{c}
                                                                                               000863
       DO 51 I=1.N
       LAMFIL=C1/SQRT(OMEG*OMEG-FCNST(I))
                                                                                               000864
                                                                                               099865
       LAMR(I) = LAMFIL/LAMRES(I)
       LREAC=2.0*(LAMRES(I)-LAMFIL)/LAMDEL(I)
                                                                                               000866
                                                                                               000867
       SET UP THE COMPLEX IMPEDANCE MATRIX OF THE FILTERS
                                                                                               000868
                                                                                               000869
                                                                                               000870
       DO 52 J=1,M
       DO 52 K=1,M
Z(I,J,K)=CMPLX(0.0,CM(I,J,K))*LAMR(I)**CEL(I,J,K)
                                                                                               000871
                                                                                               000872
                                                                                               000873
   52 CONTINUE
                                                                                               000874
                                                                                               000875
Č
       SET UP DIAGONAL ELEMENTS INCLUDING FILTER DISPERSION
                                                                                               000876
```

Fig. 1 Listing of the subroutine SIMUL.

```
DO 53 J=1,M
                                                                                        000877
                                                                                        000878
       Z(I,J,J) = CMPLX(0.0,CM(I,J,J) + LREAC)
                                                                                        000879
C
       INCLUDE FILTER DISSIPATION
                                                                                        000880
                                                                                        000881
       IF(IFLAGDP.EQ. 1) Z(I,J,J) = Z(I,J,J) + DISP(I)
                                                                                        000882
                                                                                        000883
   53 CONTINUE
   51 CONTINUE
                                                                                        000884
                                                                                        000885
       GO TO 75
                                                                                        000886
C
  500 CONTINUE
                                                                                        000887
       DO 106 I=1, N
                                                                                        000888
       XR=WO(I)/BW(I)
                                                                                        000889
       C3=(OMEG/WO(I))-(WO(I)/OMEG)
                                                                                        000890
       S=CMPLX(0.0,C3)
                                                                                        000891
                                                                                        000892
       SD=S*XR
C
                                                                                        000893
C
       SET UP DIAGONAL ELEMENTS FOR ZERO FILTER DISPERSION
                                                                                        000894
                                                                                        000895
       DO 106 J=1,M
                                                                                        000896
       Z(I,J,J) = CMPLX(0.0,CM(I,J,J)) + SD
                                                                                        000897
                                                                                        000898
C
       INCLUDE FILTER DISSIPATION
                                                                                        000899
C
Ċ
                                                                                        000900
       IF(IFLAGDP.EQ.1)Z(I,J,J)=Z(I,J,J)+DISP(I)
                                                                                        000901
       CONTINUE
                                                                                        000902
  106
C
                                                                                        000903
                                                                                        000904
   75 CONTINUE
       IF(IFLAGJS.EQ. 1)GO TO 68
                                                                                        000905
       DO 66 I=1, N
YC(I)=CMPLX(0.0,0.0)
                                                                                        000906
                                                                                        000907
       Y1(I) = CMPLX(0.0,0.0)
                                                                                        000908
   66 CONTINUE
                                                                                        000909
                                                                                        000910
       GO TO 70
                                                                                        000911
\mathbf{C}
   68 CONTINUE
                                                                                        000912
C
                                                                                        000913
       THE JUNCTION SUSCEPTANCE IS CALCULATED
C
                                                                                        000914
                                                                                        000915
       BETAJS=FCUT/(((20.0*(CBR/OMEG)**2)-1.0)*SQRT(OMEG*OMEG-FCUT*FCUT))
                                                                                        000916
       DO 69 I=1,N
                                                                                        000917
       YC(1) = (0.0, 0.0)
                                                                                        099918
       Y1(I) = CMPLX(0.0, -BETAJS)
                                                                                        000919
   69 CONTINUE
                                                                                        000920
\mathbf{c}
                                                                                        000921
   70 CONTINUE
                                                                                        000922
C
                                                                                        009923
       CALL BETAVAL(C1,C2,OMEG,P12,BETA)
                                                                                        000924
\mathbf{c}
                                                                                        000925
       CALL FILTER(N, M, Z, P, Q)
                                                                                        000926
                                                                                        009927
C
       CALL FILAECD(N,M,P,Q,PN1,PN2,Y1,GL,YC,Y,YP,YIN,Y3,
Y3SQ,TF,H7,H8,H13,H14,PN11,PN12,PN22)
                                                                                        000928
                                                                                        000929
C
                                                                                        090930
       CALL WGUIDE(N, BETA, WGL, TG, DTG)
                                                                                        000931
\mathbf{C}
                                                                                        000932
       DO 121 I=1.N
                                                                                        000933
C
                                                                                        000934
       CALL MATMUL(TF(1,1),TF(1,2),TF(1,3),TF(1,4),TG(1,1),TG(1,2),
TG(1,3),TG(1,4),T(1,1),T(1,2),T(1,3),T(1,4))
                                                                                        000935
                                                                                        000936
                                                                                        000937
C
  121 CONTINUE
                                                                                        000938
C
                                                                                        000939
       CALL SEQUENC(N, NP1, T, A)
                                                                                        000940
\mathbf{c}
                                                                                        000941
```

Fig. 1 (continued) Listing of the subroutine SIMUL.

	CALL RESPONS(N, NP1, RS, ZIN, RLOSS, VL, A, H23, H1, RO, RCOEFF,	000942
	+ YC, YP, TG, Y1, VS, H2, H3, H4, H5, H6, H7, H9, H10)	000943
C		000944
	CALL INSOUT(N, VL, INLOSS)	000945
C		000946
	CALL PHASE(N, VL, ANGLE)	009947
C		000948
	RETURN	000949
	END	009950
C		000951

Fig. 1 (continued)

Listing of the subroutine SIMUL.

SUBROUTINE TOTAL2

SUBROUTINE TOTAL2 (N, IR, IRT, IPN1, IPN2, IWG)

Purpose

This subroutine calculates the total number of variables accumulated after each section.

List of Arguments

All arguments are defined in the main program except IRT, which is the total number of variables after each section.*

Related Software

This subroutine is called from the main program MXSOS2 if the options of sensitivity analysis or optimization are selected.

Footnote

For an explanation of * see FEATURES.

C		SUBROUTINE TOTAL2(N, IR, IRT, IPN1, IPN2, IWG)	001038 001039
C		Boblico IIII Io III III III III III III III I	001040
č		CALCULATE THE TOTAL NUMBER OF VARIABLES ACCUMULATED AFTER	001041
č		EACH SECTION	001042
č			001043
_		INTEGER IR(16), IRT(16), IPN1(16), IPN2(16), IWG(16)	001044
		IRT(1)=IR(1)+IPN1(1)+IPN2(1)+IWG(1)	001045
		IF(N.EQ.1) GO TO 5	001046
		DO 15 I=2,N	001047
		IM1=I-1	001048
		IRT(1) = IRT(IM1) + IR(1) + IPN1(1) + IPN2(1) + IWG(1)	001049
	15	CONTINUE	001050
		CONTINUE	001051
	_	RETURN	001052
		END	001053
C			001054

Fig. 1 Listing of the subroutine TOTAL2.

SUBROUTINE DABCDF2

SUBROUTINE DABCFD2 (N, M, IR, IRT, IPN1, IPN2, LC, KC, DYP11, DYP21, DYP22,
YIN, P, Q, PN1, PN2, PN11, PN12, PN22, H7, H13, H14, Y1,
TG, D, Y3SQ, YP, LAMR, IDISPER)

COMMON/BLK7/CEL

Purpose

This subroutine calculates the derivatives of the filter-junction combination ABCD matrices w.r.t. variable coupling elements and variable input-output transformer ratios. These derivatives are then stored in a designated array which contains the derivatives of the ABCD matrices of the complete sections (including waveguide spacings) w.r.t. all variables (including section lengths) contained in them.

Theory

Recalling the definitions of impedance matrix (\mathbf{Z} or $\overline{\mathbf{Z}}$) from SIMUL (eqns. (1) and (6)), and denoting both matrices by \mathbf{Z} for simplicity, we have

$$\frac{\partial \mathbf{Z}}{\partial \mathbf{M}_{\ell k}} = \mathbf{j} \mathbf{w}_1 \mathbf{w}_2 (\mathbf{e}_{\ell} \mathbf{e}_k^{\mathrm{T}} + \mathbf{e}_k \mathbf{e}_{\ell}^{\mathrm{T}})$$
 (1)

where

$$\mathbf{w}_{1} = \begin{cases} 1 & \text{if } \ell \neq \mathbf{k} \\ 0.5 & \text{if } \ell = \mathbf{k} \end{cases}$$
 (2)

and

$$\mathbf{w}_{2} = \left\{ \begin{array}{c} (\lambda_{r})^{\mathbf{C}} \ell \mathbf{k} \\ \\ 1 \end{array} \right., \quad \text{if dispersion is included}, \tag{3}$$

Using (10) of FILTER, we have

$$\frac{\partial \mathbf{y}}{\partial \mathbf{M}_{\ell k}} = - j \mathbf{w}_1 \mathbf{w}_2 \begin{bmatrix} 2 p_{\ell} p_k & p_{\ell} q_k + p_k q_{\ell} \\ p_{\ell} q_k + p_k q_{\ell} & 2 q_{\ell} q_k \end{bmatrix}, \tag{4}$$

and referring to (1) of FILABCD, we get [1]

Equations (9) of FILTER and (4) give all the terms required for evaluation of (5), once **p** and **q** of FILTER (6) and FILTER (8) are known.

Recalling (2) and (3) of FILABCD, we have

$$\frac{\partial Y_{in}}{\partial \Phi} = -Y_{in}^{2} \left[\frac{\partial}{\partial \Phi} y_{11}^{\prime} - \frac{\partial y_{21}^{\prime}}{y_{22}^{\prime} + G_{L}} \left(\frac{\partial y_{21}^{\prime}}{\partial \Phi} \right) + \left(\frac{y_{21}^{\prime}}{y_{22}^{\prime} + G_{L}} \right)^{2} \left(\frac{\partial y_{22}^{\prime}}{\partial \Phi} \right) \right], \tag{6}$$

where $\phi \in \{M_{\ell k}, n_1, n_2\}$.

We can utilize (4) and (5) of FILABCD and the fact that Y_1 and Y_c are independent of Φ , to show

$$\frac{\partial \mathbf{T}_{\mathbf{f}}}{\partial \Phi} = \frac{-1}{\mathbf{Y}_{3}^{2}} \frac{\partial \mathbf{Y}_{in}}{\partial \Phi} \begin{bmatrix} \mathbf{Y}_{1} & \mathbf{1} \\ \mathbf{Y}_{1}^{2} & \mathbf{Y}_{1} \end{bmatrix} . \tag{7}$$

At this point, we can refer to RESPONS (1)-(7) and INSOUT (2) to observe that both common port return loss and channel insertion loss sensitivity analyses require the evaluation of $\partial (\mathbf{A}_{1,N+1})/\partial \Phi$. As indicated in the comments for SEQUENC, we have

$$\frac{\partial}{\partial \Phi} (\mathbf{A}_{1,N+1}) = \mathbf{A}_{j+1,N+1} \left(\frac{\partial}{\partial \Phi} \mathbf{T}_{j} \right) \mathbf{A}_{1,j}, \tag{8}$$

where ϕ is assumed to be in section j. From (1) of SEQUENC, we conclude that

$$\mathbf{D} = \frac{\partial \mathbf{T}}{\partial \Phi} = \begin{cases} \left(\frac{\partial}{\partial \Phi} \mathbf{T}_{f}\right) \mathbf{T}_{g} &, \text{ if } \Phi \in \{\mathbf{M}_{\ell k}, \mathbf{n}_{1}, \mathbf{n}_{2}\} \\ \mathbf{T}_{f} \left(\frac{\partial}{\partial \Phi} \mathbf{T}_{g}\right) &, \text{ if } \Phi = \ell \end{cases}$$

$$(9)$$

In DABCDF2, we have calculated $(\partial T_f/\partial \phi)$, hence, we fill matrix **D** partially.

List of Arguments and COMMON Blocks

N is the number of channels.

M is the order of the matrix.

IR, IPN1, IPN2, LC, KC are as defined in the main program MXSOS2.*

IRT

is as defined in TOTAL2.*

DYP11

is $\partial y_{11}'/\partial \Phi$ as defined in (5)

DYP21

is $\partial y_{21}'/\partial \varphi$ as defined in (5).

DYP22

is $\partial y_{22}'/\partial \Phi$ as defined in (5).

YIN, P, Q, PN1, PN2, PN11, PN12, PN22, H7, H13, H14, Y1, Y3SQ, YP are as defined in

FILABCD.*

TG

is as defined in WGUIDE.*+

LAMR

is λ_r defined by (4) of SIMUL.

D

is as defined by (9).*

IDISPER

is as defined in the main program MXSOS2.

Related Software

This subroutine is called from SIMGRD2.

Reference

[1] J.W. Bandler, S.H. Chen, S. Daijavad and W. Kellermann, "Optimal design of multicavity filters and contiguous-band multiplexers", <u>Proc. 14th European Microwave Conf.</u> (Liège, Belgium, Sept. 1984).

Footnote

For an explanation of * and * see FEATURES.

```
000301
\mathbf{c}
        SUBROUTINE DABCDF2(N,M,IR,IRT,IPN1,IPN2,LC,KC,DYP11,DYP21,DYP22,YIN,P,Q,PN1,PN2,PN11,PN12,PN22,H7,H13,H14,Y1,TG,D,Y3SQ,YP,
                                                                                                            000302
                                                                                                            000303
                                                                                                            000304
                               LAMR, IDISPER)
                                                                                                            000305
                                                                                                            000306
        CALCULATE DERIVATIVES OF THE FILTER-JUNCTION ABCD MATRICES W.R.T. VARIABLE COUPLING ELEMENTS, AS WELL AS INPUT/OUTPUT TRANSFORMER RATIOS, AND STORE THEM IN A DESIGNATED ARRAY FOR THE DERIVATIVES OF THE ABCD MATRICES OF THE SECTIONS W.R.T. ALL VARIABLES CONTAINED IN THEM
                                                                                                            000307
C
                                                                                                            000308
                                                                                                            000309
                                                                                                            000310
                                                                                                            000311
                                                                                                            009312
        INTEGER IR(16), IRT(16), IPN1(16), IPN2(16), LC(16,36), KC(16,36)
REAL PN1(16), PN2(16), PN11(16), PN12(16), PN22(16), LAMR(16)
INTEGER CEL(16,8,8)
                                                                                                            099313
                                                                                                            009314
                                                                                                            000315
         COMPLEX DY11, DY21, DY22, DYP11(100), DYP21(100), DYP22(100)
                                                                                                            000316
        COMPLEX DYIN, DAF, DBF, DCF, DDF
COMPLEX P(16,8),Q(16,8),Y1(16),H15,H7(16),H13(16),H14(16)
                                                                                                            009317
                                                                                                            000318
                                                                                                            000319
         COMPLEX TG(16,4),D(100,4),YIN(16),YINSQ,JPLX,Y3SQ(16),YP(16,4)
         COMPLEX H72
                                                                                                            000320
                                                                                                            009321
         COMMON/BLK7/CEL
                                                                                                            000322
         JPLX=CMPLX(0.0,1.0)
                                                                                                            000323
C
                                                                                                            000324
        DO 21 I=1,N
YINSQ=YIN(I)*YIN(I)
                                                                                                            000325
                                                                                                            000326
         H72=2.0*YP(I,2)/H7(I)
                                                                                                            000327
         IM1= I-1
                                                                                                            000328
         IF(IR(I).EQ.0)GO TO: 10
                                                                                                            000329
\mathbf{C}
                                                                                                            000330
         DO 22 J=1,KP
                                                                                                            000331
                                                                                                            000332
C
                                                                                                            000333
         IX3=LC(I,J)
                                                                                                            009334
         IX4=KC(I,J)
                                                                                                            000335
C
         IF(I.EQ. 1) GO TO 23
                                                                                                            000336
                                                                                                            000337
         IV=IRT(IM1)+J
                                                                                                            000338
        GO TO 24
    23 IV=J
                                                                                                            000339
                                                                                                            000340
    24 CONTINUE
                                                                                                            000341
C
         IF(IX3.EQ.IX4)GO TO 35
                                                                                                            000342
                                                                                                            000343
C
        DY11=-2.0*JPLX*P(I,IX3)*P(I,IX4)
DY21=-JPLX*(P(I,IX3)*Q(I,IX4)+P(I,IX4)*Q(I,IX3))
DY22=-2.0*JPLX*Q(I,IX3)*Q(I,IX4)
                                                                                                            000344
                                                                                                            000345
                                                                                                            000346
                                                                                                            000347
\mathbf{c}
         IF(IDISPER.NE.1)GO TO 36
                                                                                                            000348
         CF=LAMR( I) **CEL( I, IX3, IX4)
                                                                                                            000349
                                                                                                            000350
         DY11=DY11*CF
                                                                                                            000351
         DY21=DY21*CF
                                                                                                            000352
         DY22=DY22*CF
                                                                                                            009353
         GO TO 36
                                                                                                            000354
C
    35 DY11=-JPLX*P(I,IX3)*P(I,IX3)
DY21=-JPLX*P(I,IX3)*Q(I,IX3)
                                                                                                            000355
                                                                                                            000356
         DY22=-JPLX*Q(I,IX3)*Q(I,IX3)
                                                                                                            009357
C
                                                                                                            000358
    36 CONTINUE
                                                                                                            000359
C
                                                                                                            000360
         DYP11(IV)=PN11(I)*DY11
                                                                                                            000361
                                                                                                            000362
         DYP21(IV) = PN12(I) *DY21
                                                                                                            000363
         DYP22(IV)=PN22(I)*DY22
                                                                                                            000364
C
         DYIN=DYP11(IV)-DYP21(IV)*H72+DYP22(IV)*H13(I)
                                                                                                            000365
```

Fig. 1 Listing of the subroutine DABCDF2.

```
000366
C
                                                                                           000367
       USE AN IMPEDANCE INVERTER
C
                                                                                           Ø99368
                                                                                           009369
       DYIN=-YINSQ*DYIN
                                                                                           000370
C
                                                                                           000371
       H15=-DYIN/Y3SQ(I)
                                                                                           000372
\mathbf{C}
                                                                                           000373
       DAF=Y1(I)*H15
                                                                                           009374
       DBF=H15
       DCF=H15*H14(I)
                                                                                           000375
                                                                                           000376
                                                                                           000377
\mathbf{C}
       CALL MATMUL(DAF, DBF, DCF, DDF, TG(I, 1), TG(I, 2),
TG(I, 3), TG(I, 4), D(IV, 1), D(IV, 2), D(IV, 3), D(IV, 4))
                                                                                           000378
                                                                                           000379
                                                                                           000380
C
    22 CONTINUE
                                                                                           000381
                                                                                           000382
\mathbf{c}
    10 CONTINUE
                                                                                           000383
        IF((IPN1(I)+IPN2(I)).EQ.0)GO TO 21
                                                                                           000384
                                                                                           000385
        IF(IPN1(I).EQ.0)GO TO 11
                                                                                           000386
\mathbf{c}
                                                                                           000387
       J = IR(I) + 1
       IF(I.EQ. 1) GO TO 12
                                                                                           000388
        IV= IRT( IM1)+J
                                                                                           000389
    GO TO 13
12 IV=J
                                                                                           000390
                                                                                           000391
                                                                                           000392
    13 CONTINUE
                                                                                           000393
C
       DYP11(IV)=2.0*PN1(I)*P(I,1)
                                                                                           000394
       DYP21(IV)=PN2(I)*Q(I,1)
DYP22(IV)=(0.0,0.0)
DYIN=DYP11(IV)-DYP21(IV)*H72
                                                                                           000395
                                                                                           000396
                                                                                           000397
       DYIN=-YINSQ*DYIN
                                                                                           000398
                                                                                           000399
C
                                                                                           000400
       H15=-DYIN/Y3SQ(I)
       DAF=Y1(I)*H15
                                                                                           000401
                                                                                           000402
       DBF=H15
                                                                                           000403
       DCF=H15*H14(I)
                                                                                           000404
       DDF=DAF
                                                                                           000405
C
       CALL MATMUL(DAF, DBF, DCF, DDF, TG(1,1), TG(1,2), TG(1,3), TG(1,4), D(IV,1), D(IV,2), D(IV,3), D(IV,4))
                                                                                           000406
                                                                                           009407
                                                                                           000408
C
    11 CONTINUE
                                                                                           000409
                                                                                           000410
       IF(IPN2(I).EQ.0)GO TO 21
       J=IR(I)+IPN1(I)+1
                                                                                           000411
        IF(I.EQ. 1) GO TO 15
                                                                                           009412
        IV=IRT(IM1)+J
                                                                                           000413
                                                                                           000414
       GO TO 16
                                                                                           000415
    15 IV=J
                                                                                           000416
    16 CONTINUE
                                                                                           000417
C
                                                                                           000418
       DYP11(IV) = (0.0, 0.0)
       DYP21(IV) = PN1(I) *Q(I, 1)
                                                                                           000419
       DYP22(IV)=2.0*PN2(I)*Q(I,M)
                                                                                           000420
       DYIN=-DYP21(IV)*H72+DYP22(IV)*H13(I)
                                                                                           000421
                                                                                           000422
       DYIN=-YINSQ*DYIN
                                                                                           000423
C
                                                                                           000424
       H15 = -DYIN/Y3SQ(I)
       DAF=Y1(I)*H15
                                                                                           009425
       DBF=H15
                                                                                           000426
       DCF=H15*H14(I)
                                                                                           000427
       DDF = DAF
                                                                                           000428
                                                                                           000429
C
       CALL MATMUL(DAF, DBF, DCF, DDF, TG(I, 1), TG(I, 2), TG(I, 3), TG(I, 4),
                                                                                           000430
```

Fig. 1 (continued) Listing of the subroutine DABCDF2.

+ D(IV,1),D(IV,2),D(IV,3),D(IV,4))

C 21 CONTINUE RETURN END

Fig. 1 (continued)

Listing of the subroutine DABCDF2.

SUBROUTINE DABCDG2

SUBROUTINE DABCDG2 (N, IRT, IWG, D, DG)

<u>Purpose</u>

In this subroutine, we store the derivatives of the ABCD matrices of the complete sections w.r.t. section lengths in the designated array which contains the derivatives w.r.t. all variables in the sections.

Theory

Recalling (9) of DABCDF2, we know that matrix D is only partially filled. Now, $\partial T_g/\partial \ell$ which is already calculated in WGUIDE (eqn. (2)) is premultiplied by T_f in SIMGRD2 and the results are stored appropriately in D to complete the evaluation of D.

List of Arguments

N is the number of channels.

IRT is as defined in TOTAL2.*

IWG is as defined in the main program MXSOS2.*

D is as defined by (9) of DABCDF2.+

DG is $T_f(\partial T_g/\partial \varphi)$ for $\varphi = \ell$ in (9) of DABCDF2.*+

Related Software

This subroutine is called from SIMGRD2.

Footnote

For an explanation of * and * see FEATURES.

```
000437
\mathbf{c}
          SUBROUTINE DABCDG2(N, IRT, IWG, D, DG)
                                                                                                                                   000438
                                                                                                                                   000439
000000
          STORE THE CALCULATED DERIVATIVES OF THE ABCD MATRICES OF THE WAVEGUIDE SPACINGS W.R.T. SPACINGS (FROM SUBROUTINE WGUIDE) IN THE DESIGNATED DERIVATIVE ARRAY OF THE ABCD MATRICES OF THE SECTIONS (ONLY FOR THOSE SPACINGS WHICH ARE VARIABLES)
                                                                                                                                   000440
                                                                                                                                   000441
                                                                                                                                   000442
                                                                                                                                   000443
                                                                                                                                   000444
          INTEGER IRT(16), H20, IWG(16)
COMPLEX D(100,4), DG(16,4)
                                                                                                                                   000445
                                                                                                                                   000446
                                                                                                                                   000447
C
                                                                                                                                   000448
          DO 40 I=1,N
                                                                                                                                   000449
\mathbf{c}
          IF(IWG(I).EQ.0)GO TO 40
                                                                                                                                   000450
          H20= IRT( I)
                                                                                                                                   000451
                                                                                                                                   000452
C
                                                                                                                                   000453
     DO 42 J=1,4
D(H20,J)=DG(I,J)
42 CONTINUE
                                                                                                                                   000454
                                                                                                                                   000455
     40 CONTINUE
                                                                                                                                   000456
                                                                                                                                   009457
          RETURN
                                                                                                                                   000458
          END
                                                                                                                                   000459
C
```

Fig. 1 Listing of the subroutine DABCDG2.

SUBROUTINE DRLOSS2

SUBROUTINE DRLOSS2 (N, NP1, IRT, E, F, A, D, H23, RCOEFF, RO, DRTLOSS)

Purpose

This subroutine calculates the sensitivities of common port return loss w.r.t. all variables.

Theory

Having completed the evaluation of matrix ${\bf D}$ of (9) in DABCDF2 (completed in DABCDG2), we can calculate $\partial ({\bf A}_{1,N+1})/\partial \varphi$ of DABCDF2 (8) in two steps:

$$\mathbf{E} = \mathbf{D} \, \mathbf{A}_{1,j} \tag{1}$$

and

$$\mathbf{F} = \frac{\partial}{\partial \Phi} \left(\mathbf{A}_{1,N+1} \right) = \mathbf{A}_{j+1,N+1} \mathbf{E} . \tag{2}$$

Denoting the (1, 1), (1, 2), (2, 1) and (2, 2) elements of the 2×2 matrices $\mathbf{A}_{1,N+1}$ and \mathbf{F} by superscripts 1, 2, 3 and 4, respectively, (1) of RESPONS can be rewritten as

$$Z_{in} = \frac{A_{1,N+1}^2}{A_{1,N+1}^4} , \qquad (3)$$

and this gives

$$\frac{\partial Z_{in}}{\partial \Phi} = \frac{F^2 A_{1,N+1}^4 - F^4 A_{1,N+1}^2}{(A_{1,N+1}^4)^2} . \tag{4}$$

Utilizing (2) and (3) of RESPONS, we get

$$\frac{\partial \rho}{\partial \Phi} = \frac{2R_S}{(Z_{in} + R_S)^2} \frac{\partial Z_{in}}{\partial \Phi}$$
 (5)

and

$$\frac{\partial L_R}{\partial \Phi} = \frac{-20}{(\ln 10) |\rho|^2} \operatorname{Re} \left(\bar{\rho} \frac{\partial \rho}{\partial \Phi} \right), \tag{6}$$

where $\overline{\rho}$ is the complex conjugate of ρ .

List of Arguments

N is the number of channels.

NP1 is N+1.

IRT is as defined in TOTAL2.*

E is as defined by (1).+

F is as defined by (2).+

A is as defined in SEQUENC.+

D is as defined by (9) of DABCDF2.⁺

H23 is defined in the VARIABLES section.[†]

RCOEFF, RO are as defined in RESPONS.

DRTLOSS is the sensitivity of the common port return loss w.r.t. all variables as given

by (6).

Related Software

This subroutine is called from SIMGRD2.

<u>Footnote</u>

For an explanation of *, + and † see FEATURES

```
\mathbf{c}
                                                                                            000460
       SUBROUTINE DRLOSS2(N, NP1, IRT, E, F, A, D, H23, RCOEFF, RO, DRTLOSS)
                                                                                            000461
C
                                                                                            009462
       CALCULATE SENSITIVITIES OF COMMON PORT RETURN LOSS W.R.T.
                                                                                            000463
C
       ALL VARIABLES
                                                                                            000464
C
                                                                                             000465
       INTEGER IRT(16)
                                                                                            000466
       COMPLEX E(100,4),F(100,4),A(17,17,4),D(100,4),H23,RCOEFF
COMPLEX DZIN,H21,DRCFF,H212
                                                                                            000467
                                                                                            009468
       REAL DRTLOSS(100)
                                                                                            009469
C
                                                                                            000470
       KP=IRT(1)
                                                                                            000471
\mathbf{c}
                                                                                            000472
       IF(KP.EQ.0)GO TO 10
DO 50 J=1,KP
DO 53 K=1,4
                                                                                            000473
                                                                                            000474
                                                                                            000475
C
                                                                                            000476
   E(J,K)=D(J,K)
53 CONTINUE
                                                                                            000477
                                                                                            000478
\mathbf{C}
                                                                                            000479
       CALL MATMUL(A(2,NP1,1),A(2,NP1,2),A(2,NP1,3),A(2,NP1,4),D(J,1),
                                                                                            000480
                      D(J,2),D(J,3),D(J,4),F(J,1),F(J,2),F(J,3),F(J,4))
                                                                                            000481
C
                                                                                            099482
    50 CONTINUE
                                                                                            000483
    10 CONTINUE
                                                                                            000484
\mathbf{c}
                                                                                            000485
       IF(N.EQ. 1) GO TO 54
                                                                                            000486
       DO 51 I=2,N
                                                                                            000487
       IM1= I-1
                                                                                            000488
       IF(IRT(I).EQ.IRT(IM1))GO TO 51
                                                                                            000489
       JB = IRT(IM1) + 1
                                                                                            000490
       JE=IRT(I)
                                                                                            000491
       IP1=I+1
                                                                                            000492
C
                                                                                            000493
       DO 52 J=JB, JE
                                                                                            000494
C
                                                                                            000495
       CALL MATMUL(D(J,1),D(J,2),D(J,3),D(J,4),A(1,1,1),A(1,1,2),
                           A(1, 1, 3), A(1, 1, 4), E(J, 1), E(J, 2), E(J, 3), E(J, 4))
                                                                                            000497
\mathbf{C}
                                                                                            000498
       CALL MATMUL(A(IP1,NP1,1),A(IP1,NP1,2),A(IP1,NP1,3),A(IP1,NP1,4),

E(J,1),E(J,2),E(J,3),E(J,4),F(J,1),F(J,2),F(J,3),

F(J,4))
                                                                                            000499
                                                                                            000500
                                                                                            000501
\mathbf{c}
                                                                                            000502
   52 CONTINUE
                                                                                            000503
   51 CONTINUE
                                                                                            000504
   54 CONTINUE
                                                                                            000505
C
                                                                                            000506
       H21=1.0/(A(1,NP1,4)*A(1,NP1,4))
H211=-20.0/(ALOG(10.0)*RO*RO)
                                                                                            000507
                                                                                            000508
       H212=CONJG(RCOEFF)
                                                                                            000509
C
                                                                                            000510
       KP=IRT(N)
                                                                                            000511
       DO 55 J=1,KP
                                                                                            000512
C
                                                                                            000513
       DZIN=H21*(A(1,NP1,4)*F(J,2)-A(1,NP1,2)*F(J,4))
                                                                                            000514
       DRCFF=H23*DZIN
                                                                                            000515
       DRTLOSS(J) = H211*REAL(H212*DRCFF)
                                                                                            000516
   55 CONTINUE
                                                                                            009517
       RETURN
                                                                                            000518
       END
                                                                                            000519
\mathbf{c}
                                                                                            000520
```

Fig. 1 Listing of the subroutine DRLOSS2...

SUBROUTINE DVOLTA2

SUBROUTINE DVOLTA2 (N, IRT, IR, IPN1, IPN2, IWG, VS, H4, TG, H6, RS, DVL, F, H5, H3, H1, YC, Y1, H10, H8, H9, YP, H7, DYP21, DYP22, DYP11, DTG, A, E)

<u>Purpose</u>

This subroutine calculates the sensitivities of channel output voltages w.r.t. all variables.

Theory

Referring to eqn. (7) of RESPONS, we can write

$$V_L^i = \frac{jK_1}{K_2K_3} , \qquad (1)$$

where

$$K_1 = [Y_1^i \quad 1] T_g^i A_{1,i} e_2 V_S$$
, (2)

$$K_{2} = \left(\frac{(y_{22} + G_{L})(1 + Y_{c}y_{11})}{y_{21}} - Y_{c}y_{21}\right)^{i}, \tag{3}$$

and

$$K_3 = [1 \quad R_S] A_{1 N+1} e_2.$$
 (4)

If we assume that the variable φ is in section j, we can consider three different cases for evaluating sensitivitites of (1).

<u>Case 1</u> Section j is to the right of section i in Fig. 2 of RESPONS, i.e., j < i. In this case, K_2 is independent of the variable and we have

$$\frac{\partial V_{L}^{i}}{\partial \Phi} = \frac{j \left[\left(\frac{\partial K_{1}}{\partial \Phi} \right) K_{2} K_{3} - \left(\frac{\partial K_{3}}{\partial \Phi} \right) K_{1} K_{2} \right]}{\left(K_{2} K_{3} \right)^{2}} . \tag{5}$$

We can write

$$\frac{\partial K_{1}}{\partial \Phi} = [Y_{1}^{i} \quad 1] T_{g}^{i} \left(\frac{\partial}{\partial \Phi} A_{1,i}\right) e_{2} V_{S}$$
(6)

and

$$\frac{\partial}{\partial \Phi} \mathbf{A}_{1,i} = \mathbf{A}_{j+1,i} \left(\frac{\partial}{\partial \Phi} \mathbf{T}_{j} \right) \mathbf{A}_{1,j}$$

$$= \mathbf{A}_{j+1,i} \mathbf{E}_{j}, \tag{7}$$

where E is defined by (1) in DRLOSS2.

Also, we have

$$\frac{\partial K_3}{\partial \Phi} = \begin{bmatrix} 1 & R_S \end{bmatrix} \frac{\partial \mathbf{A}_{1,N+1}}{\partial \Phi} \mathbf{e}_2$$

$$= \begin{bmatrix} 1 & R_S \end{bmatrix} \mathbf{F}_i \mathbf{e}_2, \tag{8}$$

where F is defined by (2) in DRLOSS2.

<u>Case 2</u> The variable is in the same section as the output voltage, i.e., i = j. In this case, we have

$$\frac{\partial V_{L}^{i}}{\partial \Phi} = \begin{cases} j \left[\frac{\partial K_{1}}{\partial \Phi} - \left(\frac{\partial K_{3}}{\partial \Phi} \right) K_{1} K_{2} \\ K_{2} K_{3} - \frac{\left(K_{2} K_{3} \right)^{2}}{\left(K_{2} K_{3} \right)^{2}} \right] & , \text{ if } \Phi = \ell \\ - j \left[\left(\frac{\partial K_{2}}{\partial \Phi} \right) K_{1} K_{3} + \left(\frac{\partial K_{3}}{\partial \Phi} \right) K_{1} K_{2} \right] \\ K_{2} K_{3}^{2} & , \text{ if } \Phi \in \{M_{\ell k}, n_{1}, n_{2}\} \end{cases}$$

$$(9)$$

and

$$\frac{\partial K_{1}}{\partial \Phi} = [Y_{1}^{i} \quad 1] \left(\frac{\partial T_{g}^{i}}{\partial \Phi}\right) A_{1,i} e_{2} V_{S}, \tag{10}$$

where $\partial T_g^{\ i}/\partial \varphi$ has been calculated already in WGUIDE (eqn. (2)). Also,

$$\frac{\partial K_{2}}{\partial \Phi} = \frac{(y_{22} + G_{L}) Y_{c}}{y_{21}} \left(\frac{\partial y_{11}}{\partial \Phi}\right) + \frac{(1 + Y_{c} y_{22})}{y_{21}} \left(\frac{\partial y_{22}}{\partial \Phi}\right) \\
- \left(Y_{c} + \frac{(y_{22} + G_{L})(1 + Y_{c} y_{11})}{(y_{22})^{2}}\right) \left(\frac{\partial y_{21}}{\partial \Phi}\right), \tag{11}$$

where the superscript i for y_{11}' , y_{21}' , y_{22}' , Y_c and G_L has been omitted. $\partial K_3/\partial \varphi$ is calculated as in (8).

<u>Case 3</u> Section j is to the left of section i in Fig. 2, i.e., j > i. In this case, we have

$$\frac{\partial V_{L}^{i}}{\partial \Phi} = \frac{-j K_{1} K_{2} \frac{\partial K_{3}}{\partial \Phi}}{(K_{2} K_{3})^{2}}$$
(12)

where $\partial K_3/\partial \Phi$ is calculated as in (8).

List of Arguments

N is the number of channels.

IRT is as defined in TOTAL2.*

IR, IPN1, IPN2, IWG are as defined in the main program MXSOS2.*

VS, RS are as defined in RESPONS.

TG, DTG are as defined in WGUIDE.*+

YC, Y1, YP are as defined in FILABCD.*

H4, H6, H5, H3, H1, H10, H8, H9, H7 are defined in the VARIABLES section.*

DVL is the sensitivity of channel output voltage w.r.t. all variables as given by (5),

(9) and (12).*

F is as defined by DRLOSS2 (2).+

DYP11, DYP21, DYP22 are as defined in DABCDF2.

A is as defined in SEQUENC.⁺

E is as defined by DRLOSS2 (1).+

Related Software

This subroutine is called from SIMGRD2.

Footnote

For an explanation of * and * see FEATURES.

```
\mathbf{C}
                                                                                              000521
       SUBROUTINE DVOLTA2(N, IRT, IR, IPN1, IPN2, IWG, VS, H4, TG, H6, RS,
                                                                                              000522
      + DVL, F, H5, H3, H1, YC, Y1, H10, H8, H9, YP, H7, DYP21, DYP22, DYP11,
                                                                                              000523
                        DTG, A, E)
                                                                                              000524
                                                                                              009525
       CALCULATE SENSITIVITIES OF ALL OUTPUT VOLTAGES W.R.T. ALL
                                                                                              000526
C
                                                                                              000527
C
       VARIABLES
                                                                                              000528
       INTEGER IRT(16), IR(16), IPN1(16), IPN2(16), IWG(16), UPB, UPBP1
                                                                                              099529
       COMPLEX A(17,17,4), E(100,4), DAI(100,4), Y1(16), TG(16,4)
COMPLEX DVL(16,100), F(100,4), YC(16), YP(16,4)
COMPLEX DH2, DYP21(100), DYP22(100), DYP11(100), DTG(16,4)
                                                                                              000530
                                                                                              009531
                                                                                              000532
       COMPLEX H3(16), H4(16), H5(16), H6(16), H7(16), H8(16), H9(16), H10(16)
                                                                                              000533
       COMPLEX JPLX, H1
                                                                                              000534
                                                                                              000535
       COMPLEX H29, H30, H31, H32, H35, H36, H37, H50, H51, H52, H40, H41, H42, H43
       JPLX=CMPLX(0.0,1.0)
                                                                                              000536
C
                                                                                              000537
                                                                                              000538
       DO 60 I=1.N
                                                                                              000539
C
       H29=-VS*H4(I)
                                                                                              000540
       H30=(Y1(I)*TG(I,1)+TG(I,3))*H29
                                                                                              000541
       H31=(Y1(I)*TG(I,2)+TG(I,4))*H29
                                                                                              000542
       H32=H6(I)*RS
                                                                                              000543
C
                                                                                              000544
       H35=H3(I)*H1/H5(I)
H36=H6(I)/H5(I)
                                                                                              000545
                                                                                              000546
                                                                                              000547
       H37=H36*RS
C
                                                                                              000548
       H40=(Y1(I)*DTG(I,1)+DTG(I,3))*A(1,I,2)
H41=(Y1(I)*DTG(I,2)+DTG(I,4))*A(1,I,4)
                                                                                              000549
                                                                                              000550
       H42=VS*(H40+H41)
                                                                                              000551
       H43=-H42/H4(I)
                                                                                              090552
                                                                                              009553
\mathbf{c}
       H50=-YC(I)-H10(I)/H8(I)
                                                                                              000554
       H51=H9(I)/YP(I,2)
                                                                                              000555
       H52=H7(I)*YC(I)/YP(I.2)
                                                                                              000556
C
                                                                                              000557
                                                                                              000558
       UPB=IRT(I)
       IF(UPB.EQ.0)GO TO 10
                                                                                              000559
       IM1=I-1
                                                                                              000560
       IF(I.EQ. 1) GO TO 70
                                                                                              099561
C
                                                                                              000562
       LOB= IRT( IM1)
                                                                                              000563
       IF(LOB.EQ.0)GO TO 70
                                                                                              000564
                                                                                              000565
C
                                                                                              000566
       DO 62 JJ=1, IM1
       ISECT= IR(JJ) + IPN1(JJ) + IPN2(JJ) + IWG(JJ)
                                                                                              000567
       IF(ISECT.EQ.0)GO TO 62
                                                                                              000568
                                                                                              000569
       LL=IRT(JJ)
                                                                                              009570
       KK=LL-ISECT+1
                                                                                              000571
C
                                                                                              000572
       DO 63 J=KK, LL
                                                                                              000573
C
                                                                                              000574
       CALL MATMUL(A(JJP1,I,1),A(JJP1,I,2),A(JJP1,I,3),A(JJP1,I,4),

E(J,1),E(J,2),E(J,3),E(J,4),DAI(J,1),DAI(J,2),

DAI(J,3),DAI(J,4))
                                                                                              000575
                                                                                              000576
                                                                                              000577
C
                                                                                              000578
   63 CONTINUE
                                                                                              000579
   62 CONTINUE
                                                                                              000580
                                                                                              000581
C
                                                                                              000582
       DO 65 J=1,LOB
       DVL(I,J) = (H30*DAI(J,2)+H31*DAI(J,4)+H6(I)*F(J,2)+H32*F(J,4))/H5(I)
                                                                                              000583
       DVL(I,J) = -JPLX*DVL(I,J)
                                                                                              000584
   65 CONTINUE
                                                                                              009585
```

Fig. 1 Listing of the subroutine DVOLTA2.

```
C
                                                                                              000586
       IF(IRT(I).EQ.IRT(IM1))GO TO 10
                                                                                              009587
       GO TO 72
                                                                                              000588
\mathbf{C}
                                                                                              000589
                                                                                              009590
   70 LOB=0
C
                                                                                              000591
   72 LOB1=LOB+1
                                                                                              000592
       DO 66 J=LOB1, UPB
IF(J.NE.UPB) GO TO 30
IF(IWG(I).NE.1) GO TO 30
                                                                                              009593
                                                                                              000594
                                                                                              000595
                                                                                              000596
\mathbf{c}
       DVL(I,J)=H43+H36*F(J,2)+H37*F(J,4)
DVL(I,J)=-JPLX*DVL(I,J)
                                                                                              000597
                                                                                              000598
                                                                                              000599
C
       GO TO 66
                                                                                              000600
C
                                                                                              000601
   30 CONTINUE
                                                                                              000602
       DH2=H50*DYP21(J)+H51*DYP22(J)+H52*DYP11(J)
                                                                                              000603
                                                                                              000604
\mathbf{c}
       DVL(I,J) = H35*DH2+H36*F(J,2)+H37*F(J,4)
                                                                                              000605
       DVL(I,J)=-JPLX*DVL(I,J)
                                                                                              000606
   66 CONTINUE
                                                                                              000607
C
                                                                                              000608
   10 KP=IRT(N)
                                                                                              000609
       IF(UPB.EQ.KP)GO TO 60
UPBP1=UPB+1
                                                                                              000610
                                                                                              000611
       DO 67 J=UPBP1, KP
DVL(I,J)=H36*F(J,2)+H37*F(J,4)
                                                                                              000612
                                                                                              000613
       DVL(I,J) = -JPLX*DVL(I,J)
                                                                                              009614
C
                                                                                              000615
   67 CONTINUE
                                                                                              009616
   60 CONTINUE
RETURN
                                                                                              009617
                                                                                              000618
       END
                                                                                              000619
C
                                                                                              000620
```

Fig. 1 (continued) Listing of the subroutine DVOLTA2.

SUBROUTINE INSERT

SUBROUTINE INSERT (N, VL, DVL, INLOSS, DINLOSS, IRT)

Purpose

This subroutine calculates the channel insertion loss and its sensitivities using channel output voltage and its sensitivities.

Theory

The channel insertion loss is given by (1) and (2) in INSOUT. From (2) of INSOUT, we get

$$\frac{\partial I_L^i}{\partial \Phi} = \frac{-20}{(\ln 10)|V_L^i|^2} \operatorname{Re}\left(\overline{V_L^i}\right) \frac{\partial V_L^i}{\partial \Phi}\right)$$
(1)

where $\partial V_L^{\ i}/\partial \varphi$ is obtained from (5), (9) and (12) of DVOLTA2 and $V_L^{\ i}$ signifies the complex conjugate of $V_L^{\ i}$.

List of Arguments

N is the number of channels.

VL is the complex channel output voltage.*

DVL is $\partial V_L/\partial \varphi$.*

INLOSS is the channel insertion loss in dB.*

DINLOSS is the sensitivity of channel insertion loss $\partial I_L/\partial \phi$.*

IRT is as defined in TOTAL2.

Related Software

This subroutine is called form SIMGRD2.

Footnote

For a explanation of * see FEATURES.

C			000786
		SUBROUTINE INSERT(N, VL, DVL, INLOSS, DINLOSS, IRT)	000787
C			000788
Č		CHANNEL INSERTION LOSS AND ITS SENSITIVITIES ARE CALCULATED	000789
Č			000790
_		COMPLEX VL(16),DVL(16,100),HH2	000791
		REAL INLOSS(16), DINLOSS(16, 100)	000792
		INTEGER IRT(16)	000793
C			000794
C		THIS SUBROUTINE IS WRITTEN FOR VS=1.0, RS=1.0, GL(I)=1.0	000795
C			000796
_		HH0=-20.0/ALOG(10.0)	000797
		KP=IRT(N)	000798
		DO 10 I=1,N	000799
		VABS=CABS(VL(I))	000800
		INLOSS(I)=-20.0*ALOG10(2.0*VABS)	000801
		HH1=HH0/(VABS*VABS)	000802
		HH2=CONJG(VL(I))	000803
C			000804
		DO 20 J=1,KP	000805
		DINLOSS(I,J)=HH1*REAL(HH2*DVL(I,J))	000806
	20	CONTINUE	000807
	10	CONTINUE	000808
		RETURN	000809
		END	000810
C			000811

Fig. 1 Listing of the subroutine INSERT.

SUBROUTINE SIMGRD2

SUBROUTINE SIMGRD2 (OMEG, RLOSS, DRTLOSS, INLOSS, DINLOSS, N, M, ICOUNT, IFLAGJS, IFLAGDP, IDISPER)

COMMON/BLK1/WO, BW, PN1, PN2, GL, VS, RS, PI2, WIDTH, NP1

COMMON/BLK2/CM, WGL

COMMON/BLK4/CBR, FCUT

COMMON/BLK5/DISP

COMMON/BLK6/FCNST, LAMRES, LAMDEL

COMMON/BLK7/CEL

COMMON/BLK8/IR, IRT, IPN1, IPN2, IWG, LC, KC

Purpose

This subroutine sets up the complex **Z** matrix and calls the subroutines necessary for a complete simulation and sensitivity analysis.

Theory

Refer to the theoretical part of SIMUL for setting up ${\bf Z}$ in accordance with the options of dissipation, dispersion and nonideal junction susceptances.

List of Arguments and COMMON Blocks

The definition of arguments and common blocks can be found in the main program MXSOS2, as well as CONST1, DISPAT and DISPER.

Related Software

This subroutine is called from the main program MXSOS2 and FDF2.

```
000621
\mathbf{C}
        SUBROUTINE SIMGRD2(OMEG, RLOSS, DRTLOSS, INLOSS, DINLOSS, N, M,
                                                                                                        000622
                                                                                                        000623
                                ICOUNT, IFLAGJS, IFLAGDP, IDISPER)
                                                                                                        000624
\mathbf{c}
                                                                                                        099625
        THIS SUBROUTINE CALLS ALL OTHER SUBROUTINES NECESSARY TO
\mathbf{C}
        CALCULATE THE RESPONSE AND EXACT SENSITIVITIES
                                                                                                        009626
C
                                                                                                        000627
        COMPLEX Z(16,8,8),P(16,8),Q(16,8)

COMPLEX Y(16,4),YP(16,4),YIN(16),Y1(16),Y3(16),YC(16)

COMPLEX TF(16,4),TG(16,4),T(16,4),A(17,17,4),Y3SQ(16)

COMPLEX H2(16),H3(16),H4(16),H5(16),H6(16),H7(16),H8(16)

COMPLEX H9(16),H10(16),H13(16),H14(16)
                                                                                                        099628
                                                                                                        009629
                                                                                                        000630
                                                                                                        009631
                                                                                                        000632
        COMPLEX VL(16)
                                                                                                        000633
        COMPLEX H1, H23, ZIN, RCOEFF
                                                                                                        000634
                                                                                                        000635
        COMPLEX S,SD
                                                                                                        009636
        REAL CM(16,8,8), PN1(16), PN2(16), PN11(16), PN12(16)

REAL PN22(16), GL(16), WGL(16)

REAL INLOSS(16), DINLOSS(16,100)

REAL DISP(16), LAMR(16)
        REAL WO(16), BW(16)
                                                                                                        009637
                                                                                                        000638
                                                                                                        000639
                                                                                                        000640
        REAL FCNST(16), LAMRES(16), LAMDEL(16), LAMFIL, LREAC
                                                                                                        000641
        INTEGER IR(16), IRT(16), LC(16,36), KC(16,36), CEL(16,8,8)
INTEGER IPN1(16), IPN2(16), IWG(16)
                                                                                                        000642
                                                                                                        000643
                                                                                                        000644
        COMPLEX DYP11(100), DYP21(100), DYP22(100)
                                                                                                        000645
        COMPLEX D(100,4)
        COMPLEX DTG(16,4),DG(16,4)
COMPLEX E(100,4),F(100,4)
                                                                                                        000646
                                                                                                        000647
        REAL DRTLOSS(100)
COMPLEX DVL(16,100)
                                                                                                        000648
                                                                                                        000649
                                                                                                        000650
C
        COMMON/BLK1/WO, BW, PN1, PN2, GL, VS, RS, P12, WIDTH, NP1
                                                                                                        009651
                                                                                                        009652
        COMMON/BLK2/CM, WGL
                                                                                                        000653
        COMMON/BLK4/CBR, FCUT
                                                                                                        009654
        COMMON/BLK5/DISP
        COMMON/BLK6/FCNST, LAMRES, LAMDEL
                                                                                                        000655
        COMMON/BLK7/CEL
                                                                                                        000656
        COMMON/BLK8/IR, IRT, IPN1, IPN2, IWG, LC, KC
                                                                                                        000657
                                                                                                        000658
C
                                                                                                        000659
        IF(ICOUNT.NE.1)GO TO 5
                                                                                                        009660
C
        DO 100 I=1,N
DO 100 J=1,M
DO 100 KK=1,J
                                                                                                        000661
                                                                                                        000662
                                                                                                        000663
                                                                                                        000664
         CM(I,J,KK) = CM(I,KK,J)
                                                                                                        000665
  100 CONTINUE
                                                                                                        000666
C
        DO 99 I=1, N
DO 99 J=1, M
DO 99 K=1, M
                                                                                                        009667
                                                                                                        000668
                                                                                                        000669
                                                                                                        000670
        Z(I,J,K) = CMPLX(0.0,CM(I,J,K))
                                                                                                        000671
    99 CONTINUE
                                                                                                        000672
\mathbf{C}
        C1=11802.85
                                                                                                        000673
                                                                                                        009674
        C2=4.0*WIDTH*WIDTH
                                                                                                        000675
\mathbf{C}
                                                                                                        000676
     5 CONTINUE
                                                                                                        000677
\mathbf{c}
                                                                                                        000678
        IF(IDISPER.NE.1)GO TO 500
\mathbf{C}
                                                                                                        000679
        DO 51 I=1, N
                                                                                                        009680
        LAMFIL=C1/SQRT(OMEG*OMEG-FCNST(I))
                                                                                                        000681
        LAMR( I) = LAMFIL/LAMRES( I)
                                                                                                        000682
                                                                                                        000683
        LREAC=2.0*(LAMRES(I)-LAMFIL)/LAMDEL(I)
                                                                                                        000684
        SET UP THE COMPLEX IMPEDANCE MATRIX OF THE FILTERS
                                                                                                        000685
```

Fig. 1 Listing of the subroutine SIMGRD2.

```
C
                                                                                        000686
       DO 52 J=1,M
                                                                                        000687
       DO 52 K=1, M
                                                                                        000688
       Z(I,J,K) = CMPLX(0.0,CM(I,J,K))*LAMR(I)**CEL(I,J,K)
                                                                                        000689
   52 CONTINUE
                                                                                        000690
                                                                                        000691
\mathbf{c}
       SET UP DIAGONAL ELEMENTS INCLUDING FILTER DISPERSION
                                                                                        000692
C
                                                                                        000693
C
       DO 53 J=1,M
                                                                                        000694
       Z(I,J,J) = CMPLX(0.0,CM(I,J,J) + LREAC)
                                                                                        000695
                                                                                        000696
C
       INCLUDE FILTER DISSIPATION
                                                                                        000697
                                                                                        000698
       IF(IFLAGDP.EQ.1)Z(I,J,J)=Z(I,J,J)+DISP(I)
                                                                                        000699
                                                                                        000700
   53 CONTINUE
                                                                                        000701
       CONTINUE
   51
                                                                                        000702
       GO TO 75
                                                                                        000703
\mathbf{C}
  500 CONTINUE
                                                                                        000704
       DO 106 I=1, N

KR=WO(1)/BW(I)

C3=(OMEG/WO(I))-(WO(I)/OMEG)
                                                                                        000705
                                                                                        000706
                                                                                        000707
       S=CMPLX(0.0,C3)
                                                                                        000708
                                                                                        000709
       SD=S*XR
                                                                                        000710
\mathbf{c}
       SET UP DIAGONAL ELEMENTS FOR ZERO FILTER DISPERSION
                                                                                        000711
C
C
                                                                                        000712
       DO 106 J=1, M
                                                                                        000713
       Z(I,J,J) = CMPLX(0.0,CM(I,J,J)) + SD
                                                                                        000714
\mathbf{C}
                                                                                        000715
       INCLUDE FILTER DISSIPATION
                                                                                        000716
C
                                                                                        000717
C
       IF(IFLAGDP.EQ. 1) Z(I,J,J) = Z(I,J,J) + DISP(I)
                                                                                        000718
                                                                                        000719
  106
                                                                                        000720
C
   75 CONTINUE
                                                                                        000721
       IF(IFLAGJS.EQ.1)GO TO 68
                                                                                        000722
       DO 66 I=1, N
YC(I)=CMPLX(0.0,0.0)
                                                                                        000723
                                                                                        000724
                                                                                        000725
       Y1(I) = CMPLX(0.0,0.0)
                                                                                        000726
   66 CONTINUE
       GO TO 70
                                                                                        000727
                                                                                        000728
C
   68 CONTINUE
                                                                                        000729
                                                                                        000730
       THE JUNCTION SUSCEPTANCE IS CALCULATED .
                                                                                        000731
C
                                                                                        000732
C
       BETAJS=FCUT/(((20.0*(CBR/OMEG)**2)-1.0)*SQRT(OMEG*OMEG-FCUT*FCUT))
                                                                                        000733
       DO 69 I=1,N
YC(I)=(0.0,0.0)
                                                                                        000734
                                                                                        000735
       Y1(I) = CMPLX(0.0, -BETAJS)
                                                                                        000736
   69 CONTINUE
                                                                                        000737
\mathbf{c}
                                                                                        000738
                                                                                        000739
   70 CONTINUE
                                                                                        000740
\mathbf{C}
       CALL BETAVAL(C1,C2,OMEG,P12,BETA)
                                                                                        000741
                                                                                        000742
C
       CALL FILTER(N, M, Z, P, Q)
                                                                                        000743
                                                                                        000744
\mathbf{C}
       CALL FILABCD(N, M, P, Q, PN1, PN2, Y1, GL, YC, Y, YP, YIN, Y3,
                                                                                        000745
                      Y3SQ, TF, H7, H8, H13, H14, PN11, PN12, PN22)
                                                                                        000746
                                                                                        000747
\mathbf{c}
       CALL WGUIDE(N, BETA, WGL, TG, DTG)
                                                                                        000748
                                                                                        000749
\mathbf{c}
       DO 121 I=1,N
                                                                                        000750
```

Fig. 1 (continued) Listing of the subroutine SIMGRD2.

```
C
                                                                                                 000751
        CALL MATMUL(TF(I,1),TF(I,2),TF(I,3),TF(I,4),TG(I,1),TG(I,2),
                                                                                                 000752
                     TG(I,3),TG(I,4),T(I,1),T(I,2),T(I,3),T(I,4))
                                                                                                 000753
\mathbf{C}
                                                                                                 000754
   121 CONTINUE
                                                                                                 000755
\mathbf{c}
                                                                                                 000756
        CALL SEQUENC(N, NP1, T, A)
                                                                                                 000757
C
                                                                                                 000758
       CALL RESPONS(N, NP1, RS, ZIN, RLOSS, VL, A, H23, H1, RO, RCOEFF, YC, YP, TG, Y1, VS, H2, H3, H4, H5, H6, H7, H9, H10)
                                                                                                 000759
                                                                                                 000760
C
                                                                                                 000761
       000762
                                                                                                 000763
                                                                                                 000764
                           LAMR, IDISPER)
                                                                                                 000765
C
                                                                                                 000766
       DO 125 I=1,N
                                                                                                 000767
C
                                                                                                 000768
       CALL MATMUL(TF(1,1),TF(1,2),TF(1,3),TF(1,4),DTG(1,1),DTG(1,2),
DTG(1,3),DTG(1,4),DG(1,1),DG(1,2),DG(1,3),DG(1,4))
                                                                                                 000769
                                                                                                 000770
C
                                                                                                 000771
  125 CONTINUE
                                                                                                 000772
C
                                                                                                 000773
        CALL DABCDG2(N, IRT, IWG, D, DG)
                                                                                                 000774
C
                                                                                                 009775
       CALL DRLOSS2(N, NP1, IRT, E, F, A, D, H23, RCOEFF, RO, DRTLOSS)
                                                                                                 000776
\mathbf{c}
                                                                                                 000777
      CALL DVOLTA2(N, IRT, IR, IPN1, IPN2, IWG, VS, H4, TG, H6, RS, DVL, F, H5, H3, H1, YC, Y1, H10, H8, H9, YP, H7, DYP21, DYP22, DYP11, DTG, A, E)
                                                                                                 000778
                                                                                                 000779
C
                                                                                                 000780
       CALL INSERT(N, VL, DVL, INLOSS, DINLOSS, IRT)
                                                                                                 000781
C
                                                                                                 000782
       RETURN
                                                                                                 000783
       END
                                                                                                 000784
\mathbf{c}
                                                                                                 000785
```

Fig. 1 (continued) Listing of the subroutine SIMGRD2.

INTERMEDIATE VARIABLES

Symbol	Mathematical Expression
H1	$\begin{bmatrix} 1 & R_S \end{bmatrix} A_{1,N+1} e_2$
*H2	$\frac{(\dot{y}_{22} + G_L)(1 + Y_c \dot{y}_{11})}{\dot{y}_{21}} - Y_c \dot{y}_{21}$
*H3	$[Y_1 1] T_g^i A_{1,i} e_2 V_S$
*H4	(H2)(H1)
*H5	$(H4)^2$
*H6	(H3)(H2)
* H7	$y_{22} + G_L$
*H8	$(y_{21})^2$
*H9	$1 + Y_c y_{11}'$
*H10	(H7)(H9)
*H13	$\left(\frac{y_{21}}{y_{21} + G_L}\right)^2$
*H14	$(Y_1)^2$

^{*} variables which are dimensioned for the number of channels

Symbol	Mathematical Expression
H15	$-\frac{1}{(Y_3)^2} \frac{\partial Y_3}{\partial \Phi}$
H20	IRT^{i}
H21	$1/(A_{1,N+1}^4)^2$
H22	$(Z_{in} + R_S)^2$
H23	$\frac{2R_{S}}{\left(Z_{in} + R_{S}\right)^{2}}$
H29	– V _S (H4)
H30	$[Y_1 \ 1]T_g^i e_1(H29)$
H31	$[Y_1 \ 1]T_g^i e_2(H29)$
H32	R _S (H6)
H35	(H1)(H3)/(H5)
H36	(H6)/(H5)
H37	R _S (H36)
H40	$[\mathbf{Y}_{1} 1 \mid \frac{\partial \mathbf{T}_{g}}{\partial \mathbf{\Phi}} \mathbf{e}_{1} \mathbf{e}_{1}^{T} \mathbf{A}_{1,i} \mathbf{e}_{2}$

Symbol	Mathematical Expression
H41	$[Y_1 1] \frac{\partial T_g}{\partial \Phi} e_2 e_2^T A_{1,i} e_2$
H42	$[Y_1 1] \frac{\partial T_g}{\partial \varphi} A_{1,i} e_2 V_S$
H43	- (H42)/(H4)
H50	$-\left[Y_{c} + \frac{(y_{22}^{'} + G_{L})(1 + Y_{c}y_{11}^{'})}{(y_{21}^{'})^{2}}\right]$
H51	$\frac{1+Y_{c}y_{11}^{'}}{y_{21}^{'}}$
H52	$\frac{(y_{22}^{'} + G_{L})Y_{c}}{y_{21}^{'}}$
H72	$\frac{2y_{21}}{y_{22} + G_L}$
H211	$\frac{-20}{(\ell nl 0) \rho ^2}$
H212	ρ̄
HMX	$T_g^i \mathbf{A}_{1,i}$

