Using MMICAD to Synthesize Single and Coupled Transmission Lines

MMICAD users have powerful powerful synthesis routines available to allow the calculation of physical parameters for single and coupled transmission lines from electrical parameters, electrical parameters from physical parameters, as well as shared physical and electrical parameters. These routines are written into specially configured circuit files within the SYNTH sub-directory of MMICAD, and they enable users to input parameters and optimize for synthesis parameters with fast and consistent convergence.

This highly flexible synthesis approach offers several advantages over other commercially available programs:

(1) broadband frequency range synthesis
(2) ideal and lossy synthesis
(3) model range is incorporated into the optimizer to prevent unrealistic results
(4) wider range of data and synthesis parameters for practical designs
(5) users have total control over the synthesis process

Another principal advantage is that users do not have to leave the simulator environment to obtain their answers. Synthesis is done completely within MMICAD.

The available synthesis library is shown overleaf in Table 1, and includes elements such as microstrip single and coupled lines, single and coupled stripline, coplanar waveguide, coaxial line, single and coupled suspended substrate transmission line, as well as series and shunt lumped and transmission line elements. In the table, the list of elements available for synthesis are listed together with:

- * the corresponding *.CKT file present in the \MMICAD\SYNTH subdirectory.
- * the required data parameters
- * the parameters that will be synthesized.

To synthesize an element, select the corresponding CKT file in Table 1 from the \MMICAD\SYNTH directory and load it into MMICAD.

Next:
(1) Enter the element data parameters in the VAR Block
(2) Enter the substrate parameters in the VAR block
(3) If necessary, change the dimensions in the DIM statement.
(4) Optimize. Select SIMPLEX. When optimization stops, save the optimized values
(5) Restart optimization. Select TAURUS. When optimization stops, save the optimized values.
(6) View output frame "DATA" for data parameters
(7) View output frame "SYN" for synthesis parameters

Example

One of the most common applications is to attain width and length of microstrip lines from the characteristic impedance and electrical degrees data. Given these design requirements:

- 70 ohm impedance
- ¼ of a wavelength long
- frequency = 3 GHz
- 10 mil thick alumina substrate
- 0.2 mil thick gold conductor

To run this example, the user must load SYNTH21.CKT which, as indicated in Table 1, converts a TLIN element into MTRL. Input the goals as shown in Figure 1.

The results of the synthesis are shown in Figure 2. The goals may be achieved with a microstrip transmission line having W=4.3 mils, and a length of 392 mils.

Notes:

(1) The two-cycle optimization is required for consistent convergence on the correct solution. The SIMPLEX optimizer has the advantage of bringing down large error functions quickly, while the TAURUS optimizer has the advantage of converging small error functions rapidly. Results can be considered accurate when the error function reduces to ≤ 0.1

(2) If the optimized values do not converge to ≤ 1.0 , then the data selected fall outside the model validity range. The model range has been incorporated into the optimization statements to prevent erroneous results.

(3) If the optimized results do not fall substantially below 1.0, as might be encounterd with broadband frequency range, then simply restart the TAURUS optimizer until the error function falls down further.

These powerful synthesis routines allow sophisticated applications such as realizing filter networks designed by MMICAD's FAISON into distributed networks, physical matching components, and others.

CKT-NAME	the circuit file present in the \MMICAD.WIN\SYNTH subdirectory
ELEMENTs	the data element to synthesized element conversion
DATA	the required data parameters
SYNTHESIS	the parameters that will be synthesized

CKT-NAME	ELEMENTs	DATA	SYNTHESIS
SYNTH1.CKT	CLINP to MCLIN	ZE, ZO	W, S, L, KE, KO, AE, AO, ZO, C
SYNTH2.CKT	CLINP to SBCLIN	ZE, ZO, E, F	W, S, L, ZO, C
SYNTH3.CKT	CLINP to SCLIN	ZE, ZO, E, F	W, S, L, AE, AO, ZO, C
SYNTH4.CKT	CLINP to SSBCLIN	ZE, ZO, B, L	W, S, KE, KO, ZO, C
SYNTH5.CKT	COAX to TLINP	DI, DO, L, ER	ZO, E, A
SYNTH6.CKT	CPW to TLINP	W, G, L, HC	ZO, K, E, A
SYNTH7.CKT	CPWG to TLINP	W, G, L, HC	ZO, K, E, A
SYNTH8.CKT	MCLIN to CLINP	W, L	ZE, ZO, KE, KO, AE, AO, ZO, C
SYNTH9.CKT	MLANG to CLINP	W, S, L	ZE, ZO, KE, KO, AE, AO
SYNTH10.CKT	MTRL tO TLINP	W, L	ZO, K, E, A
SYNTH11.CKT	Optimal Miter	W, ANG, H, T	M
SYNTH12.CKT	Optimal Miter	W, ANG, B, T	M
SYNTH13.CKT	SCLIN to CLINP	W, S, L	ZE, ZO, Z0, C, E, AE, AO
SYNTH14.CKT	SLIN to TLINP	W, L	ZO, E, A
SYNTH15.CKT	SBCLIN to CLINP	W, S, L	ZE, ZO, C, E
SYNTH16.CKT	SSBCLIN to CLINP	W, S, L	ZE, ZO, KE, KO, ZO, C
SYNTH17.CKT	SSLIN to TLINP	W, L	ZO, Keff, E, AT
SYNTH18.CKT	TLIN to COAX	ZO, E, F, DI	N, DO, L
SYNTH19.CKT	TLIN to CPW	Z0, E, F, HC	W, G, L
SYNTH20.CKT	TLIN to CPWG	ZO, E, F, HC	W, G, L, K, A
SYNTH21.CKT	TLIN to MTRL	ZO, E, F	W, L, K, A
SYNTH22.CKT	TLIN to SLIN	ZO, E, F	W, L
SYNTH23.CKT	TLIN to SSLIN	Z0, E, F	W, L, K, AT

Table 1 Synthesis Table

FIG. 1 SYNTH21.CKT	TLIN to MTRL Synthesis	OPTOTEK LTD	MAY/1992

Data	TLIN element --- Ideal Transmission Line Z0 = ideal transmission line (TLIN) characteristic impedance E = ideal transmission line electrical length in degrees F = frequency at which the angle is Θ or E
Synthesis	MTRL element --- Microstrip Line W = conductor width L = conductor length
Range	0.1 ≤ W/H ≤ 20 1 ≤ ER ≤ 10
Reference	Jansen, R.H. and Kirchning, M., Arguments and an Accurate Model for the Power-Current Formulation of Microstrip Characteristic Impedance, Arch. Elek, Ubertragung (AEU), Vol. 37, 1983, pp 108-112 Hammerstad, E. and Jensen, O., Accurate Models for Microstrip C.A.D., MTT-S Int. Microwave Symp. Dig., 1980, pp 407-409. Pucel, R.A. et al., Losses in Microstrip, MTT-16, 1968, pp 342-350 (see also corrections in MTT-16, 1968, p 1064)

INSTRUCTIONS	(a) Insert Data and MSUB parameters in the VAR block (b) Choose the FREQ and LNG dimensions in the DIM statement (c) Insert a frequency point or range in the FREQ block (d) Optimize with SIMPLEX then TAURUS until error function < 1 (e) View the DATA frame for input data (f) View the SYN frame for output results

```
 GLOBAL
 !    FREQ=GHZ   RES=Ω COND= µS   CAP= pF    IND= nH    LNG= Mils   TIME= pSec
  DIM FREQ=1e+09 RES=1 COND=0.001 CAP=1e-012 IND=1e-009 LNG=25.4e-6 TIME=1e-012
 VAR
  Z0=70
  E=90
  F=3
  H=10
  ER=9.9
  T=0.2
  RHO=1
  TAND=0
  W=? 0.001 1 1000 ?
  L=? 0.001 1 1000 ?
 CKT
  MSUB ER=ER H=H T=T RHO=RHO TAND=TAND @SUB0
  MTRL 1 2 W=W L=L @SUB0
  DEF2P 1 2 SYN
  TLIN 1 2 0 Z=Z0 E=E F=F
  DEF2P 1 2 DATA
 FREQ
  STEP 3
 PROC
  Z0()=Z0
  E()=E
  Er()=ER
  H()=H
  T()=T
  R(⌠)=RHO
  T(δ)=TAND
  W()=W
  L()=L
  CND1=W/H
 PROC
  E11G=DATA S11
  E11S=SYN  S11
  E12G=DATA S12
  E12S=SYN  S12
  E21G=DATA S21
  E21S=SYN  S21
  E22G=DATA S22
  E22S=SYN  S22
  E11=SQR(E11S-E11G)
  E12=SQR(E12S-E12G)
  E21=SQR(E21S-E21G)
  E22=SQR(E22S-E22G)
 OPT
  OUTVAR E11 EQ 0
  OUTVAR E12 EQ 0
  OUTVAR E21 EQ 0
  OUTVAR E22 EQ 0
 OPT
  OUTVAR RE[CND1] GT 0.0999
  OUTVAR RE[CND1] LT 20.001
  OUTVAR RE[ER()] GT 0.999
  OUTVAR RE[ER()] LT 18.001
 OUT
  SYN    POL[S11] GRAPH
  DATA   POL[S11] GRAPH
  SYN    POL[S21] GRAPH
  DATA   POL[S21] GRAPH
  OUTVAR RE[Z0()] DATA T
  OUTVAR RE[E()]  DATA T
  OUTVAR RE[ER()] DATA T
  OUTVAR RE[H()]  DATA T
  OUTVAR RE[T()]  DATA T
  OUTVAR RE[R(⌠)] DATA T
  OUTVAR RE[T(δ)] DATA T
  OUTVAR RE[W()]  SYN  T
  OUTVAR RE[L()]  SYN  T
 LABEL
 TLIN to MTRL Synthesis
```

```
!  File: A:\SYNTH21.CKT
! MMICAD -- Mon Jul 05 09:56:53 1993
! TLIN to MTRL Synthesis
! FREQ    OUTVAR   OUTVAR
!         RE[W()]  RE[L()]
   3.000  4.30764  392.125
```

Figure 2