Variational Analysis Using MMICAD

"How does the gain of my amplifier vary as a function of feedback resistance?"

"What is the insertion loss for both states of my SPDT switch?"

"What is the response of my attenuator as a function of control voltage?"

"What happens to my MMIC design if I scale the transistor size?"

"What is the optimal bias point of my amplifier?"

Microwave engineers are often interested in determining the sensitivity of their designs to variations in a circuit parameter. This can be a very frustrating experience using conventional microwave CAD software. However, MMICAD users can easily plot either:

(1) response curves versus parameter variation at a fixed frequency,

(2) a "family of curves" representing the variation of the parameter against frequency.

Example

Consider the amplifier netlist shown in Figure 1. In this example, we are interested in analyzing the gain and matching response of the amplifier as a function of transistor size at the center frequency. Note that the Parameter Block is swept from 0.5 to 1.5 in steps of 0.02, and this value is assigned to the scaling of the GCF transistors (the M factor) in the LA44 network. The 'FIXED 44' statement in the FREQ block will fix the frequency at 44 GHz in Parameter mode.

```
! FILE NAME: ehf1.CKT

mode param              ! Analyze in PARAMETER mode.
files
! READ THE DATA FILE;CREATE THE NETWORK GCF
FOR THE TRANSISTOR:
```

```
var
 FO=44

!DEFINE THE IMPEDANCES AND PHASE LENGTHS:

 Z11=? 40 40 110 ?                    Z21=75.5734
 E11=? 0 47.2846 90 ?                 E21=51.4045
 Z12=? 40 100.975 200 ?               Z22=53.9624
 E12=? 0 20.4685 90 ?                 E22=47.3001
 ZSI1=? 40 105.664 200 ?              ZS14= 98.6758
 ESI1=? 0 39.4343 100 ?               ES14=67.2811
 ZSI2=? 20 20.4713 100 ?              ZS15=40.0127
 ESI2=? 0 91.8061 200 ?               ES15=82.0368
 ZSI3=? 40 165.007 200 ?              ZS16=42.3024
 ESI3=? 0 8.7697 10 ?                 ES16=4.65161
 ZSO1=? 40 40.0073 100 ?              ZSO4=40.0359
 ESO1= 0.000113434                    ESO4=5.77778
 ZSO2= 87.4251                        ZSO5=98.2158
 ESO2= 74.9854                        ESO5= 98.4258
 ZSO3=41.6769                         ZSO6= 40.6878
 ESO3=55.6144                         ESO6= 99.993
 Z15=92.6401                          Z25=98.5305
 E15=54.8657                          E25= 55.4193
 Z17=46.9032                          Z27= 72.9599
 E17=46.9581                          E27= 50.2107

! CIRCUIT DESCRIPTION:
ckt
!input matching:
 CAP 1 2 C=3
 TLOC 2 0 Z=Z11 E=E11 F=F0
 TLIN 2 3 0 Z=Z12 E=E12 F=F0
 TLIN 3 4 0 Z=ZSI1 E=ESI1 F=F0
 TLOC 4 0 Z=ZSI2 E=ESI2 F=F0
 RES 4 5 R=50
 RES 4 0 R=3000
 CAP 5 0 C=3
 TLIN 3 6 0 Z=ZSI3 E=ESI3 F=F0
 DEF2P 1 6 MATIN1

!OUTPUT MATCHING:
 TLIN 1 2 0 Z=ZSO1 E=ESO1 F=F0
 TLIN 2 3 0 Z=ZSO2 E=ESO2 F=F0
 TLOC 3 0 Z=ZSO3 E=ESO3 F=F0
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=Z15 E=E15 F=F0
 TLOC 5 0 Z=Z17 E=E17 F=F0
 CAP 5 6 C=3
 DEF2P 1 6 MATOUT1
```

Figure 1

```
!INPUT MATCHING 2:
 TLOC 1 0 Z=Z21 E=E21 F=F0
 TLIN 1 2 0 Z=Z22 E=E22 F=F0
 TLIN 2 3 0 Z=ZSO5 E=ESO5 F=F0
 TLOC 3 0 Z=ZSO6 E=ESO6 F=F0
 RES 3 0 R=5000
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=ZSO4 E=ESO4 F=F0
 DEF2P 1 5 MATIN2

!OUTPUT MATCHING 2:
 TLIN 1 2 0 Z=ZS16 E=ES16 F=F0
 TLIN 2 3 0 Z=ZS14 E=ES14 F=F0
 TLOC 3 0 Z=ZS15 E=ES15 F=F0
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=Z25 E=E25 F=F0
 TLOC 5 0 Z=Z27 E=E27 F=F0
 CAP 5 6 C=3
 DEF2P 1 6 MATOUT2

!DEFINE THE FINAL AMPLIFIER:
 MATIN1 1 2 0
 GCF 2 3 0 M=param !Transistor scales by PARAM
 MATOUT1 3 4 0 M=1
 MATIN2 4 5 0
 GCF 5 6 0 M=param          !Transistor    scales    by
PARAM
 MATOUT2 6 7 0
 DEF2P 1 7 LA44

freq
FIXED 44            !Fixed at 44 GHz in PARAM mode
sweep 42 46 .2

param
SWEEP .5 1.5 .02

opt
LA44 DB[S21] IN 15.5 .1 W=20
LA44 DB[S11] LT -5 W=1
LA44 DB[S22] LT -15

out
la44 db[s21] gain
la44 db[s11] gain r
la44 db[s22] gain r

grid
FRANGE 42 46 1
PRANGE .5 1.5 .1
gain 0 20 1 r -40 0

label
SATCOM Amp: Variational Analysis
```

Figure 1 (cont'd)

The result of the circuit simulation is shown in Figure 2. Note that this design has been optimized for a transistor scaling near unity.

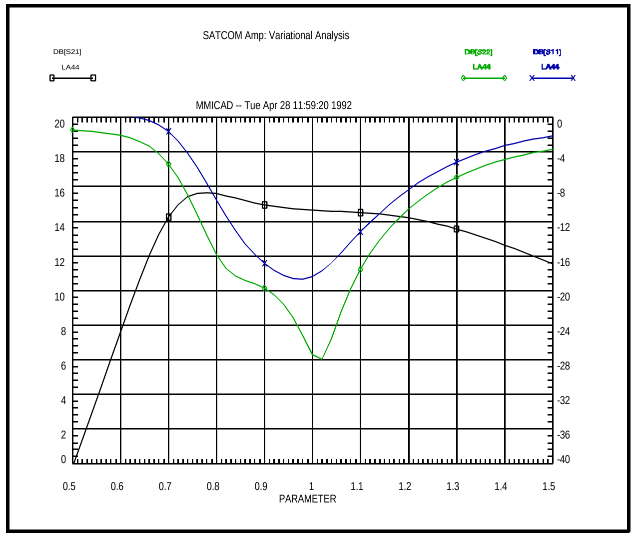

Figure 2

Next, consider the modifications to the netlist shown in Figure 3. The FILES block filename has been modified to 'AAA?.SIM' from 'AAA1.SIM'. The '?' wildcard character will be replaced by the current value of the PARAM block during analysis.

```
! FILE NAME: ehf2.CKT

! NOTES:  This file demonstrates the ability of MMICAD to read in
          a number of data files sequentially in the FILES block
          This capability may be used to assess the manufacturing
          yield of a process.
mode freq

files
! READ THE DATA FILES; CREATE THE NETWORK GCF FOR
THE TRANSISTOR: (NOTE THE ? WILDACARD)
C:\MMICAD\WORKING\AAA?.SIM GCF 101 2P FREQ
var
 F0=44
!DEFINE THE IMPEDANCES AND PHASE LENGTHS:
 Z11=? 40 40 110 ?                    E17=46.9581
 E11=? 0 47.2846 90 ?                 Z21=75.5734
 Z12=? 40 100.975 200 ?               E21=51.4045
 E12=? 0 20.4685 90 ?
 ZSI1=? 40 105.664 200 ?
 ESI1=? 0 39.4343 100 ?
 ZSI2=? 20 20.4713 100 ?
 ESI2=? 0 91.8061 200 ?
 ZSI3=? 40 165.007 200 ?
 ESI3=? 0 8.7697 10 ?
 ZSO1=? 40 40.0073 100 ?
 ESO1= 0.000113434
 ZSO2= 87.4251
 ESO2= 74.9854
 ZSO3=41.6769
 ESO3=55.6144
 Z15=92.6401
 E15=54.8657
 Z17=46.9032
```

Figure 3

```
! CIRCUIT DESCRIPTION:
ckt
!input matching:
 CAP 1 2 C=3
 TLOC 2 0 Z=Z11 E=E11 F=F0
 TLIN 2 3 0 Z=Z12 E=E12 F=F0
 TLIN 3 4 0 Z=ZSI1 E=ESI1 F=F0
 TLOC 4 0 Z=ZSI2 E=ESI2 F=F0
 RES 4 5 R=50
 RES 4 0 R=3000
 CAP 5 0 C=3
 TLIN 3 6 0 Z=ZSI3 E=ESI3 F=F0
 DEF2P 1 6 MATIN1

!OUTPUT MATCHING:
 TLIN 1 2 0 Z=ZSO1 E=ESO1 F=F0
 TLIN 2 3 0 Z=ZSO2 E=ESO2 F=F0
 TLOC 3 0 Z=ZSO3 E=ESO3 F=F0
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=Z15 E=E15 F=F0
 TLOC 5 0 Z=Z17 E=E17 F=F0
 CAP 5 6 C=3
 DEF2P 1 6 MATOUT1

!INPUT MATCHING 2:
 TLOC 1 0 Z=Z21 E=E21 F=F0
 TLIN 1 2 0 Z=Z22 E=E22 F=F0
 TLIN 2 3 0 Z=ZSO5 E=ESO5 F=F0
 TLOC 3 0 Z=ZSO6 E=ESO6 F=F0
 RES 3 0 R=5000
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=ZSO4 E=ESO4 F=F0
 DEF2P 1 5 MATIN2

!OUTPUT MATCHING 2:
 TLIN 1 2 0 Z=ZS16 E=ES16 F=F0
 TLIN 2 3 0 Z=ZS14 E=ES14 F=F0
 TLOC 3 0 Z=ZS15 E=ES15 F=F0
 RES 3 4 R=50
 CAP 4 0 C=3
 TLIN 2 5 0 Z=Z25 E=E25 F=F0
 TLOC 5 0 Z=Z27 E=E27 F=F0
 CAP 5 6 C=3
 DEF2P 1 6 MATOUT2

!DEFINE THE FINAL AMPLIFIER:
 MATIN1 1 2 0
 GCF 2 3 0 M=1                    !Transistor scaling=1
 MATOUT1 3 4 0 M=1
 MATIN2 4 5 0
 GCF 5 6 0 M=1                    !Transistor scaling=1
 MATOUT2 6 7 0
 DEF2P 1 7 LA44

freq
FIXED 44
sweep 42 46 .2

param
SWEEP 1 50 1

opt
LA44 DB[S21] IN 15.5 .1 W=20
LA44 DB[S11] LT -5 W=1
LA44 DB[S22] LT -15
out
la44 db[s21] gain
la44 db[s11] gain r
la44 db[s22] gain r
grid
FRANGE 42 46 1
PRANGE .5 1.5 .1
gain 0 20 1 r -40 0

label
SATCOM Amp: Variational Analysis
```

Figure 3 (cont'd)

In this case, since PARAM is swept from 1 to 50, MMICAD will read 50 data files that represent the variation of transistor performance in a GaAs MMIC foundry (AAA1.SIM, AAA2.SIM, AAA3.SIM, ... AAA50.SIM). MMICAD analyzed the circuit in "Variational Analysis" mode which will plot the responses as a function of frequency. The plot shown in Figure 4 clearly indicates the performance variation that may be expected from this particular foundry.

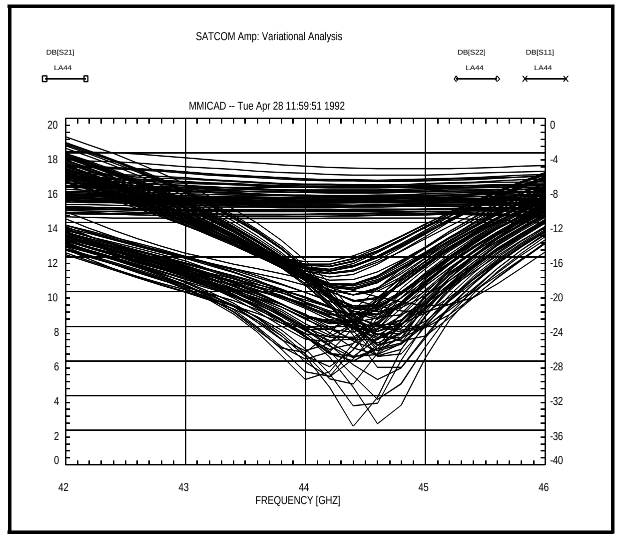

Figure 4

Obviously, the powerful parameter variation features of MMICAD can be applied to many aspects of your circuit design.