RoMPE USER'S MANUAL
Version 1.2

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RoMPE™ User's Manual

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ENHANCEMENTS OF RoMPE V1.2 wrt RoMPE V1.1

1. SMITH CHART PLOTS

Smith Chart plots are now available to display the S11 and S22 measured and modeled responses.

2. "GENERATE" OPTION

RoMPE is now capable of generating S-parameters at user specified bias points. The FET model defined in the circuit file can be analyzed at bias points of interest by capturing the small-signal model response at up to 200 discrete frequency points within a user defined frequency range. The resulting S-parameters are displayed in magnitude and phase format on screen and can optionally be written to an ascii file, or displayed in Smith Chart form (S11 and S22).

To generate S-parameters, select the ANA command. The **Generate** option will prompt the user to specify values of VDS and VGS at the bias point of interest. It will then request the lowest and highest frequency values, together with the total number of frequency points. The model response will be simulated at each frequency point.

This new feature is further documented in Chapter 5.

3. AN IMPROVED SIMULATOR

The simulator used to calculate model responses has been improved for V1.2. The numerical results from this version are more precise than those of V1.1.

4. MODIFIED MENU STRUCTURE

To incorporate future enhancements, the appearance of the Ana menu (analysis option) has been modified. Four options are now provided in the RoMPE.Ana menu: **Ac**, **Dc**, **Range** and **Generate**. Within the RoMPE.Ana.Ac submenu (small-signal analysis), the following options are now displayed: **Next**, **Previous**, **Smith Chart**, **Rectangular**, **Text** and **File**.

5. REVISED USER'S MANUAL

The RoMPE user's manual has been revised to reflect the V1.2 enhancements. Examples have also been updated.

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

RoMPE (an acronym for robust model parameter extractor) is a program dedicated to the extraction of FET model parameters from measurement data. It benefits from several years of theoretical research and incorporates the latest results published in the IEEE MTT-S International Microwave Symposium [1].

RoMPE accepts measurement data in the form of small-signal S-parameter and/or DC bias measurements. Depending on what type of data is available, RoMPE can be used to extract DC model parameters, small-signal model parameters, or, as a unique feature, both DC and small-signal parameters simultaneously.

RoMPE offers the combined power of novel techniques in device modeling and the state-of-the-art gradient-based ℓ_1 and ℓ_2 optimizers through a friendly and uncomplicated user-interface. The input file adopts a format similar to that of Super-Compact® and Microwave Harmonica™. The program is also enhanced by high-quality graphics display.

Currently, RoMPE supports two popular FET models, namely the Materka and Kacprzak model [2] and the Microwave Harmonica™ model [3].

1.2 TECHNICAL BACKGROUND

To microwave circuit designers, the ability to simulate FET devices using an equivalent circuit is very important. This requires, first of all, an appropriate topology for the equivalent circuit. Many models, nonlinear and small-signal, have been investigated in recent years. The Materka and Kacprzak model [1] and the model implemented in the Microwave Harmonica program [2] are among the most popular ones.

Given the model topology, the next critical step is to determine the model parameter values. The basic approach is to estimate the model parameters such that the equivalent circuit response will match as closely as possible the actual measurement on the device being modeled. The underlying assumption is that if the model matches the measurement at some selected points, it is deemed valid in certain operating range and can be used for simulation in that range.

The type of measurement used for modeling depends on the anticipated application of the model as well as the availability of the measurement. RoMPE accepts small-signal S-parameter and DC bias measurements as input data.

Conventionally, small-signal parameters are extracted from S-parameters measured at a single bias point. Circuit designers relying on this approach are often frustrated by nonunique solutions. Usually there exist a family of solutions, all of which produce a similar match between model response and measurement. As a consequence, the particular solution obtained depends on the initial guess: using a different starting point will probably result in a different solution.

Additional difficulties arise for large-signal nonlinear modeling, since we need to determine parameters that may vary with bias, such as drain-to-source nonlinear current source. It is obvious that small-signal S-parameter measurements at a single bias point are not adequate for extracting bias-dependent parameters.

A common practice in an attempt at "large-signal modeling", in the absence of anything better, is to extract *separately* DC and small-signal parameters. DC parameters are extracted from curve fitting, and small-signal parameters are extracted from S-parameters measured at *a single bias point* while holding the DC parameters constant. Such an approach can be an improvement from "pure small-signal modeling", since the extraction of DC parameters from curve fitting has reduced the number of unknowns to be determined from S-parameter matching. However, two problems may plague such a solution: the results may not be unique, and DC parameters extracted from DC curve fitting alone may not be valid at the operating microwave frequencies.

1.3 THE UNIQUE APPROACH TAKEN BY RoMPE

The novel approach pioneered by Bandler, Chen and Daijavad [4], recently extended by Bandler, Chen, Ye and Zhang [1] and implemented in RoMPE provides two distinct advantages. One is to process simultaneously measurements at multiple bias points, and another one to optimize simultaneously small-signal and DC parameters.

The motivation of multi-circuit modeling, i.e., modeling through simultaneous processing of multiple sets of measurements, is to strengthen the model identifiability and to enforce a unique solution. This principle has been amply demonstrated in [1,4] and is applicable to *all* engineering modeling problems. In our case, measurements at multiple bias points can be utilized to achieve a robust solution, and this can be applied to small-signal modeling, DC modeling and large-signal modeling.

The other unique feature offered by RoMPE is the *simultaneous* extraction of DC and small-signal parameters by processing DC and small-signal measurements *simultaneously*. This approach takes into account the dependence, explicit and implicit, of small-signal parameters upon the bias. It implements the theoretically established relationship between some small-signal parameters and DC parameters, such as the one between CGS (a small-signal parameter) and CG0 and VBI (DC parameters). It also allows the user to specify explicit bias-dependence or bias-independence for other small-signal parameters.

We realize that the classification of DC and AC parameters is somewhat arbitrary. Therefore, by simultaneously optimizing all the model parameters using all the available measurements, we can avoid neglecting the possible dependence of DC parameters on AC measurements, and vice versa. In other words, the DC parameters may be adjusted based on the small-signal measurements, and the small-signal parameters may be constrained by the actual biasing conditions.

RoMPE is very flexible. It accommodates various problems ranging from simple, conventional single-bias small-signal parameter extraction to sophisticated multi-bias simultaneous AC-DC modeling.

1.4 POWERFUL OPTIMIZERS

Two state-of-the-art optimizers are employed by RoMPE. The 2-stage ℓ_1 optimizer has a proven track record in circuit optimization in general and device modeling in particular [4,5]. The ℓ_2 optimizer implements a conventional least squares objective and combines the power of the Levenberg-Marquardt and the quasi-Newton methods.

The computational efficiency of RoMPE is further enhanced by adjoint sensitivity calculations which provide exact gradients for the optimization. The adjoint analysis is implemented not only for small-signal simulation, but also for the solution of the DC nonlinear equivalent circuit.

1.5 REFERENCES

[1] J.W. Bandler, S.H. Chen, S. Ye and Q.J. Zhang, "Robust model parameter extraction using large-scale optimization concepts", *1988 IEEE MTT-S International Microwave Symposium Digest* (New York, NY), pp. 319-322.

[2] A. Materka and T. Kacprzak, "Computer calculation of large-signal GaAs FET amplifier characteristics", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, 1985, pp. 129-135.

[3] *Microwave Harmonica V1.4 User's Manual*, Compact Software Inc., 483 McLean Blvd. & Corner of 18th Avenue, Paterson, NJ 07504.

[4] J.W. Bandler, S.H. Chen and S. Daijavad, "Microwave device modeling using efficient ℓ_1 optimization: a novel approach", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-34, 1986, pp. 1282-1293.

[5] J.W. Bandler, W. Kellermann and K. Madsen, "A nonlinear ℓ_1 optimization algorithm for design, modeling and diagnosis of networks", *IEEE Trans. Circuits and Systems*, vol. CAS-34, 1987, pp. 174-181.

CHAPTER 2

GETTING STARTED

2.1 INSTALLATION

The RoMPE program is shipped on a single high-density floppy disk. It contains the executable program, the auxiliary files and some examples.

The installation of RoMPE is made easy through an installation batch file INSTALL.BAT which is also included on the floppy disk. To install RoMPE, please follow these steps:

1. Insert the original RoMPE disk into a high-density floppy disk drive on your machine. Let's assume it is drive "A".

2. Type A:INSTALL followed by a drive designator indicating the destination disk on which you wish to install RoMPE. For example, if you wish to install RoMPE on your hard disk "C", type A:INSTALL C

A new directory "ROMPE" will be created and it will contain the program and the associated files. For example, if you have installed RoMPE on the "C" drive, then a "C:\ROMPE" directory will be created. If a directory by that name already exists its contents will be overwritten. The new "ROMPE" directory takes up approximately 650Kb disk space.

The hardware requirements for RoMPE are as follows.

IBM PC/AT or compatibles (both 80286 or 80386 systems)
DOS version 3.0 or higher
80287 or 80387 Math Coprocessor
EGA + Enhanced Color Display
640K RAM

RoMPE is also equipped with a security hardware key. This key must be connected to a parallel port on the host computer while RoMPE is running. It is not possible to operate RoMPE without the proper security key.

2.2 IMPORTANT TERMS

The following are some of the important terms frequently used in this manual:

Circuit file refers to an input file used to specify the essential information required by the program such as model parameter values, DC bias data, and names of the S-parameter data files.

Block refers to a distinct section in the circuit file which defines a specific type of information.

Small-signal measurements refer to small-signal S-parameter measurements under specified biasing conditions.

DC measurements refer to VDS, VGS, IDS and IGS measurements at one or more bias points.

Circuit refers to a FET small-signal equivalent circuit defined by a unique set of model parameters at a particular bias point. Multi-circuit modeling refers to the modeling techniques using AC and/or DC measurements at multiple bias points.

Optimizable parameters refer to model parameters whose values may be varied by the RoMPE optimizers in order to minimize the errors between the calculated model responses and the measurements.

Common variables refer to model parameters which have a common value between different bias points. In other words, these model parameters are assumed to be bias independent or bias insensitive.

Label is a string of one to eight characters used in a circuit file. A label may be associated with a scalar value, and then assigned to one or more circuit parameters. This is the means of defining common variables between different bias points. A label may also be associated with a specific small-signal circuit model or a set measurement data, as a "name" for later reference.

Optional entries in this Manual are delimited by a pair of square brackets "[ ]". In other words, entries enclosed within a pair of square brackets may be used but are not required.

Data directory refers to a DOS disk file directory. All the circuit files and data files for RoMPE are assumed to reside in this directory. By default, RoMPE assumes it to be the "DATA_F" directory. It can be changed using the Cdir command (see Chapter 5).

2.3 UNITS OF NUMERIC ENTRIES

RoMPE permits the use of literal units for numeric entries. In general, a numeric entry consists of a number (which may be expressed in scientific notation) and, optionally, a suffix which designates the appropriate unit. The set of units recognized by RoMPE is tabulated below. If a unit designator is used, it must NOT be separated from the numeric part of the entry. If no unit designator is used, default units are assumed as indicated in the table.

As an example, a frequency of 500 Megahertz can be entered as either "500MHZ", or "0.5GHZ", or "5E8" (the default unit Hertz is assumed), but not as "500 MHZ".

TABLE 2.1 UNIT DESIGNATORS AND DEFAULT UNITS

Unit	Default	Available options
Capacitance	F (Farad)	MF (Millifarad) UF (Microfarad) NF (Nanofarad) PF (Picofarad) FF (Femtofarad)
Conductance Transconductance	/OH (Siemens)	/KOH(Millisiemens) /MOH (Microsiemens)
Frequency	HZ (Hertz)	KHZ (Kilohertz) MHZ (Megahertz) GHZ (Gigahertz)
Inductance	L (Henry)	MH (Millihenry) UH (Microhenry) NH (Nanohenry) PH (Picohenry)
Resistance	OH (Ohm)	KOH (Kilo-ohm) MOH (Mega-ohm)
Time	SEC (Second)	MS (Millisecond) US (Microsecond) NS (Nanosecond) PS (Picosecond)
Current	A (Ampere)	MA (Milliampere) UA (Microampere) NA (Nanoampere)
Voltage	V (volt)	MV (Millivolt) UV (Microvolt)

2.4 OPTIMIZABLE PARAMETERS

Parameters designated as "optimizable" will be optimized by RoMPE. In the circuit file, optimizable parameter values should be delimited by a pair of question marks (?). For example, the entry

CGS = ?0.07PF?

indicates that the parameter CGS is optimizable with a nominal (initial) value of 0.07 picofarads.

Optimizable parameters can be constrained by upper and lower bounds. This is done using the notation

?lower_bound nominal_value upper_bound?

For example,

RG = ?1.E-3 2.5 20?

indicates that the parameter RG is optimizable, its nominal value is 2.5 ohms, and its optimized value must be between the lower bound of 1 milliohm and the upper bound of 20 ohms.

2.5 RESTRICTION ON THE SIZE OF THE PROBLEMS

The size of the problems accommodated by RoMPE is currently restricted by the following limits:

Maximum number of optimizable parameters:	50
Maximum number of different bias points:	20
Maximum number of different frequencies per bias:	30
Total number of frequencies for all bias points:	200

Optimization in RoMPE may also be limited by the amount of memory actually available on your system as well as the optimizer selected.

CHAPTER 3

FET MODELS

Two popular FET equivalent circuit models are currently supported by RoMPE. These are the Materka and Kacprzak model, and the model implemented in Microwave Harmonica.

Both models are represented by a nonlinear FET large-signal equivalent circuit and a corresponding FET small-signal equivalent circuit. Within their fixed topology, the user describes the selected model by specifying the values for the model parameters.

3.1 MATERKA AND KACPRZAK FET MODEL

3.1.1 LARGE-SIGNAL EQUIVALENT CIRCUIT: SCHEMATIC

A schematic of the FET large-signal equivalent circuit appears below.

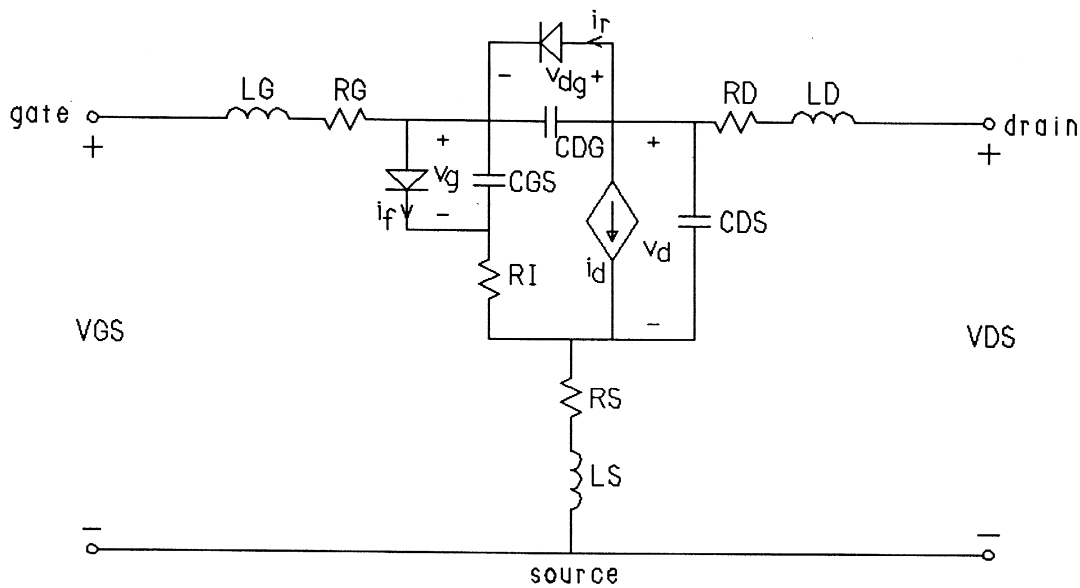


Fig. 3.1 Large-signal Materka and Kacprzak model.

3.1.2 NONLINEAR COMPONENTS

The large signal equivalent circuit model contains 4 nonlinear component:

1. CGS, the FET gate-source capacitance
2. D_f, a diode modelling the gate-channel junction current
3. D_r, a diode modelling the FET breakdown characteristics
4. i_d, the voltage controlled drain current source

These components are related to the model parameters as follows.

1. CGS, the gate-source capacitance:

$$CGS = C0*(1-v_g/VBI)^{-0.5} \quad \text{for} \quad v_g < 0.8*VBI$$

$$CGS = 5.59*C0/VBI \quad \text{for} \quad v_g \geq 0.8*VBI$$

where C0 and VBI are model parameters.

2. i_f, the current across diode D_f:

$$i_f = IS*[\exp(AS*v_g)-1]$$

where IS and AS are model parameters.

3. i_r, the current across diode D_r:

$$i_r = ISR*[\exp(ASR*v_{dg})-1]$$

where ISR and ASR are model parameters.

4. i_d, the drain current:

$$i_d = IDSS*[1-v_g/(V0+GAMA*v_d)]^2 * \tanh[ADSS*v_d/(v_g-V0-GAMA*v_d)]$$

where IDSS, V0, GAMA and ADSS are model parameters.

3.1.3 SMALL-SIGNAL EQUIVALENT CIRCUIT

The corresponding small-signal equivalent circuit model is shown in Figure 3.2.

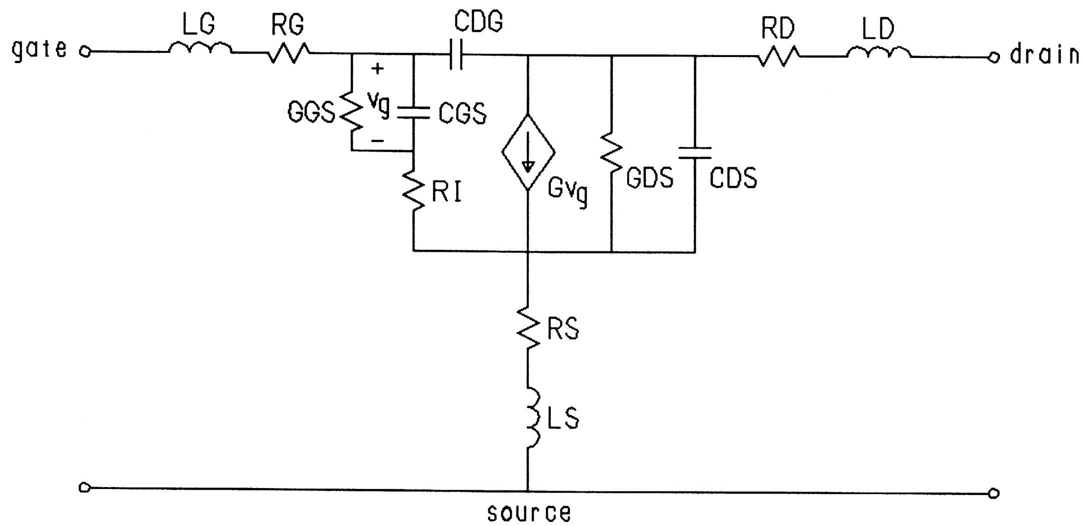


Fig. 3.2 Small-signal Materka and Kacprzak equivalent circuit.

The transconductance of the current source is defined as

$$G(f) = G*\exp[-2*\pi*f*T/(1+j*f/F)]$$

where G, T and F are model parameters.

3.1.4 MODEL PARAMETERS

The model parameters that characterize both the large- and small-signal Materka and Kacprzak equivalent circuits are presented in Table 3.1.

TABLE 3.1 MATERKA AND KACPRZAK FET MODEL PARAMETERS

Parameter	Description
ADSS	parameter describing effect of v_d on drain saturation current
AS	slope factor of gate conduction current
ASR	slope factor of breakdown current
CDS	drain-source (substrate) capacitance
CDG	gate-drain (Schottky barrier) capacitance
CGS	gate-source (Schottky barrier) capacitance
C0	gate-source capacitance at v_g=0V
F	transconductance rolloff frequency
G	transconductance magnitude at DC
GAMA	parameter relating effect of v_d on pinchoff voltage
GDS	drain to source conductance
GGS	gate to source conductance
IDSS	drain saturation current at VGS=0V
IS	Schottky barrier saturation current
ISR	channel breakdown current
LG, LD, LS	gate, drain and source inductances
RG, RD, RS	gate, drain and source resistances
RI	channel resistance
T	time delay due to carrier transit time in the channel
VBI	voltage slope parameter of gate-source capacitance
V0	pinchoff voltage at v_d=0V

3.2 MICROWAVE HARMONICA FET MODEL

This FET model is used by the Microwave Harmonica program. It is a variation of the Materka and Kacprzak FET model.

The topologies of both the large- and small-signal equivalent circuits are identical to those of the Materka and Kacprzak model, but the model parameters are referred to by different names.

3.2.1 LARGE-SIGNAL EQUIVALENT CIRCUIT

The large signal-equivalent circuit appears in Figure 3.3.

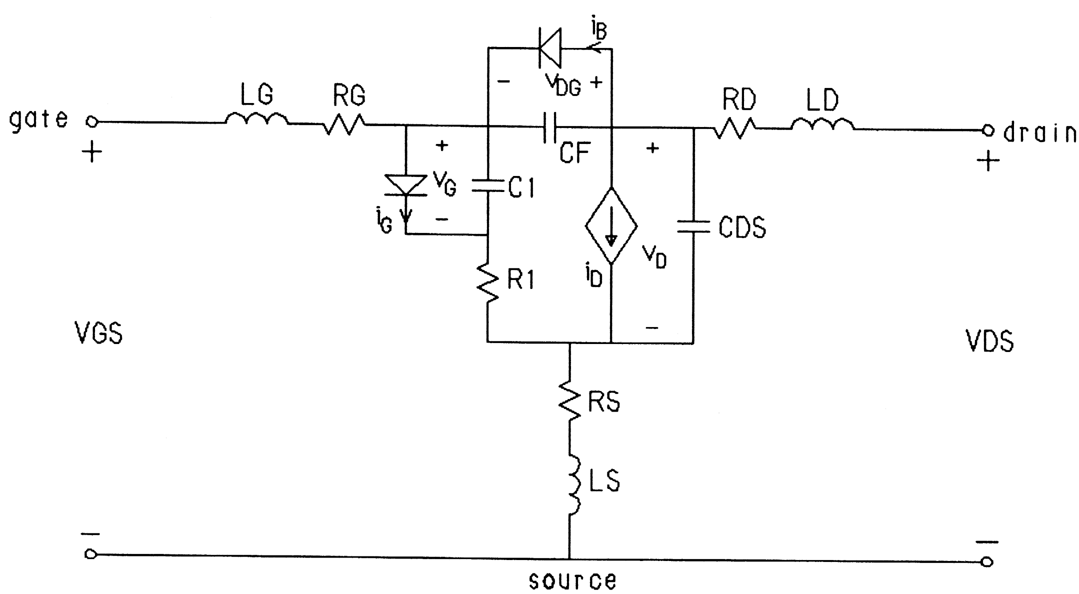


Fig. 3.3 Large-signal Microwave Harmonica model.

3.2.2 NONLINEAR COMPONENTS

The large signal model contains 4 nonlinear components:

1. C1, the FET gate-source capacitance
2. D_G, a diode representing the gate-channel junction current
3. D_B, a diode representing the gate-drain breakdown characteristics
4. i_D, the voltage controlled drain current source

These nonlinear components are defined below.

1. C1, the gate Schottky barrier capacitance:

$$C1 = C10*(1-K1*v_G)^{-0.5} \qquad \text{for } K1*v_G < 0.8$$

$$C1 = 5.59*C10 \qquad \text{for } K1*v_G \geq 0.8$$

where C10 and K1 are model parameters.

2. i_G, the current across diode D_G:

$$i_G = IG0*[\exp(AFAG*v_G)-1]$$

where IG0 and AFAG are model parameters.

3. i_B, the current across diode D_B:

$$i_B = IB0*[\exp(AFAB*v_{DG})-1]$$

where IB0 and AFAB are model parameters.

4. i_D, the drain current:

$$i_D = IDSS*[1-v_G/(VP0+GAMA*v_D)]^2 * \tanh[SL*v_D/(IDSS*(1-KG*v_G))]$$

where IDSS, VP0, GAMA, SL, IDSS and KG are model parameters.

3.2.3 FIXED PARAMETERS IN THE LARGE-SIGNAL FET MODEL

The parameters listed in Table 3.2 are introduced by Microwave Harmonica as extensions to the Materka and Kacprzak model. In RoMPE, they are fixed at constant values as given in Table 3.2, and cannot be redefined by the user.

TABLE 3.2 FIXED PARAMETERS

Parameter	Assigned Value
C1S	0.0F
E	2.0
KE	0.0/V
KF	0.0/V
KR	0.0/V
SS	0.0S
VBC	0.0V

3.2.4 SMALL-SIGNAL EQUIVALENT CIRCUIT

The small-signal equivalent circuit for the Microwave Harmonica FET model appears in Figure 3.4.

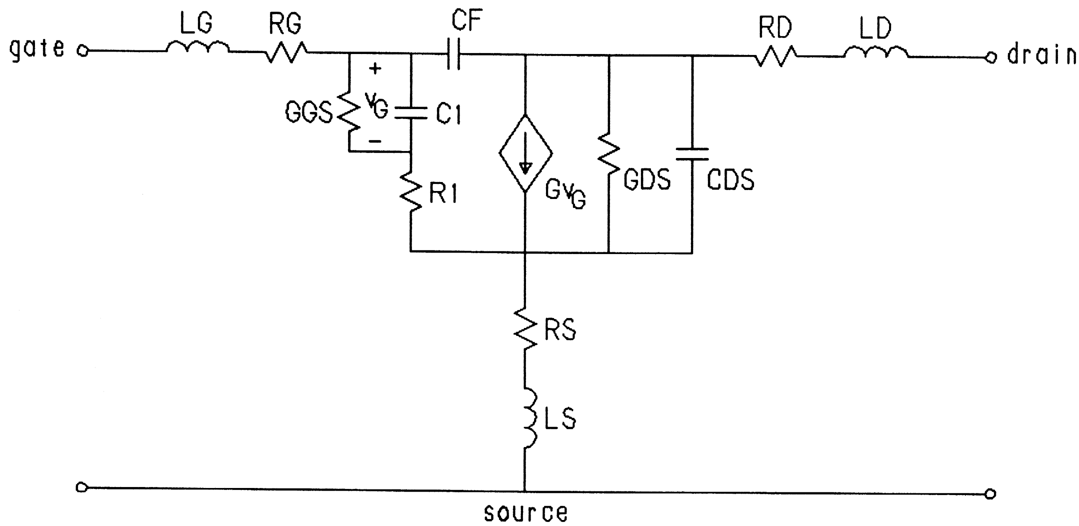


Fig. 3.4 Small-signal Microwave Harmonica equivalent circuit.

The transconductance of the current source is defined as

$$G(f) = G*\exp[-2*\pi*f*TAU/(1+j*f/F)]$$

where G, TAU and F are model parameters.

3.2.5 MODEL PARAMETERS

The model parameters that characterize both the large- and small-signal circuits are presented in Table 3.3.

TABLE 3.3 MICROWAVE HARMONICA FET MODEL PARAMETERS

Parameter	Description
AFAB	slope factor of breakdown current
AFAG	slope factor of gate conduction current
C1	Schottky barrier capacitance
C10	Schottky barrier capacitance for v_G=0V
CDS	drain-source (substrate) capacitance
CF	feedback capacitance
F	transconductance magnitude at DC
G	transconductance magnitude at DC
GAMA	voltage-slope parameter of pinchoff voltage
GDS	drain-source conductance
GGS	drain-source conductance
IB0	channel breakdown current
IDSS	drain saturation current for v_G=0V
IG0	Schottky barrier saturation current
K1	voltage slope parameter of gate capacitance
LG, LD, LS	gate, drain and source inductances
RG, RD, RS	gate, drain and source resistances
R1	intrinsic channel resistance for zero gate voltage
SL	slope of the v_G=0V drain characteristic in the linear region
TAU	time delay due to carrier transit time in the channel
VP0	pinchoff voltage for v_D=0V

CHAPTER 4

CIRCUIT FILES

4.1 UNDERSTANDING THE CIRCUIT FILE

The essential information required by RoMPE is fed into the program by means of a circuit file. The circuit file specifies, among other things, the bias points to be used, the FET model parameters values or their initial guess, designation of optimizable parameters, and names of the measurement data files.

4.1.1 THE BASIC BUILDING BLOCKS

A circuit file must contain three blocks: an MODL or MODR block, a DATA block, and an OPT block. Each block in the circuit file begins with the block name and ends with the keyword "END".

The choice of an MODL or MODR block selects the FET model: MODL implies the use of the Materka and Kacrpzak Model, and MODR the Microwave Harmonica model.

The MODL or MODR block defines scalar labels and specifies the DC and/or AC (small-signal) model parameters.

The DATA block supplies the DC bias data and/or the names of S-parameter data files.

The OPT block associates each set of measurements defined in the DATA block with a small-signal model defined in the MODL or MODR block. Weighting factors ("weights") for optimization are also defined in this block.

As an example, a complete circuit file is provided on the next page. It describes the model parameters and measurement data for three bias points. The Materka and Kacprzak model is used.

```
*
*  Circuit file: DEMO3.CKT
*  July 23/88
*
MODL
*
*  Labels
*
   R0:2E-6        F0:1000GHZ        RGM:0.0119     LS:0.0107NH
   RDD:0.0006     TAU:3.654PS       LG:0.1257NH    LD:0.0719NH
   C2:?.07PF? C3:0.1958PF    R1:?1E-5 3.4731 10? R2:?1E-5 1 10?
   C5:?.08PF? C6:0.1917PF    R4:?1E-5 4.2221 10? R5:?1E-5 1 10?
   C8:?.09PF? C9:0.1905PF    R7:?1E-5 5.5954 10? R8:?1E-5 1 10?
*
*  DC parameters defined here
*
   DC  IDSS=?0.2A?  ADSS=?4?  V0=?-4V?  GAMA=?-0.2?
+      C0=?1PF?   VBI=?1V?  IS=0.5NA      ISR=0.5NA
+      AS=20/V         ASR=1/V
*
*  Small-signal specification lines start here.
*  Small-signal FET model parameters are declared for each
*  bias point because some are bias dependent.
*
   BIAS1: FET RG=RGM RD=RDD GDS=?1.306596E-3? RI=R1 RS=R2  LS=LS CGS=
+ ?918.8831E-15? CDG=C2 CDS=C3 G=?.0798399? T=TAU LG=LG LD=LD F=F0 GGS=R0
*
   BIAS2: FET RG=RGM RD=RDD GDS=?3.945877E-3? RI=R4 RS=R5  LS=LS CGS=
+ ?595.8148E-15? CDG=C5 CDS=C6 G=?.0518374? T=TAU  LG=LG LD=LD F=F0 GGS=R0
*
   BIAS3: FET RG=RGM RD=RDD GDS=?3.787702E-3? RI=R7 RS=R8  LS=LS CGS=
+ ?492.4088E-15? CDG=C8 CDS=C9 G=?.0290667? T=TAU  LG=LG LD=LD F=F0 GGS=R0
*
END
DATA
   DAT1: S=SPAR1.DAT  VGS=0V      VDS=4V  IGS=0A  IDS=0.177A
   DAT2: S=SPAR2.DAT  VGS=-1.74V VDS=4V  IGS=0A  IDS=0.092A
   DAT3: S=SPAR3.DAT  VGS=-3.1V  VDS=4V  IGS=0A  IDS=0.037A
END
OPT
   BIAS1=DAT1   F=2GHZ 18GHZ   WS=1 1 1 1 1 1 1 1   WDC=0 100
   BIAS2=DAT2   F=2GHZ 18GHZ   WS=1 1 1 1 1 1 1 1   WDC=0 100
   BIAS3=DAT3   F=2GHZ 18GHZ   WS=1 1 1 1 1 1 1 1   WDC=0 100
END
```

4.1.2 COMMENT, BLANK AND CONTINUATION LINES

Any line in the circuit file which has an asterisk "*" as its first non-blank character is considered as a comment line. Examples of comment lines:

```
*
*  Circuit File: DEMO3.CKT
*  July 23/88
*
```

Blank lines may also be used in the circuit file for clarity.

Each line of a circuit file must not be longer than 80 characters. Continuation lines can be used to break a long line to shorter lines. A line that begins with a plus sign "+" is considered as a continuation line of the preceding line. The plus sign "+" and the text following it must be separated by one or more spaces. The following is an example of continuation lines:

```
   BIAS1: FET RG=RGM RD=RDD GDS=?1.306596E-3? RI=R1 RS=R2  LS=LS CGS=
+ ?918.8831E-15? CDG=C2 CDS=C3 G=?.0798399? T=TAU LG=LG LD=LD F=F0 GGS=R0
```

4.1.3 LABELS

The generic form of a label definition is

label_name: assignment

where label_name is a string consisting of one to eight characters.

A scalar value may be assigned to a label which is in turn assigned to one or more model parameters. For example, the following statements

```
R1: 20KOH              L0: ?5NH?

RG=R1   LG=L0   LD=L0
```

define two labels "R1" and "L0". "R1" is given a constant value and "L0" is designated as an optimizable variable with an initial value of 5NH. Then "R1" is used to specify the value of parameter RG, and "L0" is assigned to both parameters LG and LD. Therefore, both LD and LG will be optimized and they are tied to a single variable identified by the label "L0".

A label must be defined before it can be referred to, and all scalar labels must appear at the top of the MODL or MODR block.

Labels are also used to identify the small-signal model and measurement data at each bias point.

4.2 MODL BLOCK

A MODL block is used to describe the Materka and Kacprzak FET model. The schematic of this model has been described in Section 3.1.

The MODL block begins with the keyword "MODL" and ends with "END". Within the MODL block, the parameters for the small-signal and large-signal FET equivalent circuits are assigned values. The generic structure in the MODL block is

```
MODL

    [label definitions]

    [DC parameter definition]

    small-signal parameter definitions

END
```

4.2.1 DC PARAMETERS IN THE MODL BLOCK

The Materka and Kacprzak FET model contains 10 DC parameters. The definition of these parameters must begin with the key word "DC". The generic form of defining the DC parameters is as follows.

```
    DC IDSS=x1 GAMA=x2 V0=x3 VBI=x4 [ADSS=x5] [IS=x6] [ISR=x7]
+       [AS=x8] [ASR=x9] [C0=x10]
```

where

DC --> keyword indicating the declaration of DC parameters

IDSS,...,C0 --> large-signal model parameters

x1,...,x10 --> assigned parameter values

The 10 DC parameters may appear in any order.

Since the line is likely to be longer than 80 characters, one or more continuation lines may be used. The plus sign at the beginning of the second line, as shown above, indicates the presence of a continuation line.

The definition of DC parameters in the MODL block is optional. Without the DC definition, RoMPE will perform only small-signal modeling. If the DC definition is given, four of the parameters, namely IDSS, GAMA, V0 and VBI are required to be initialized by non-zero values. The other parameters are optional with a default value of zero.

4.2.2 SMALL-SIGNAL PARAMETERS IN THE MODL BLOCK

The Materka and Kacprzak small-signal equivalent circuit has 15 model parameters. They are defined as:

```
   label_name:  FET  CGS=x1  GDS=x2  G=x3  RG=x4  RD=x5  RI=x6
 +                   RS=x7  [LS=x8]  [LG=x9]  [LD=x10]  [CDG=x11]
 +                   [CDS=x12]  [T=x13]  [F=x14]  [GGS=x15]
```

where

label_name	-->	a valid label name identifying the small-signal equivalent circuit model at a particular (but as yet unspecified) bias point
FET	-->	keyword signifying a small-signal circuit model definition
CGS, ..., GGS	-->	parameters in the Materka-Kacprzak small-signal model
x1, ..., x15	-->	assigned parameter values

The small-signal parameters may appear in any order.

As many small-signal models as the number of different bias points must be defined, since in general the small-signal parameter values depend on the bias. Seven of the parameters, namely CGS, GDS, G, RG, RD, RI and RS are required. The other parameters are optional with a default value of zero.

4.2.3 FIXED AND OPTIMIZABLE PARAMETERS IN THE MODL BLOCK

All the model parameters may be optimized except for the transconductance rolloff frequency F and the parasitic conductance GGS which must remain at fixed values.

The parameter values can either be assigned directly, such as

```
FET  RG=?2.5?  CDG=?0.07PF?  ...
```

or indirectly using labels, like

```
RGM: ?2.5?   C2: ?0.07PF?  ...
       ...

FET  RG=RGM  CDG=C2  ...
```

One exceptional case arises when DC parameters are defined. In this case, three small signal parameters CGS, GDS and G are defined implicitly through the values of the bias voltages and the DC parameters. RoMPE automatically calculates the values for these three parameters from the specified DC parameters and bias voltages, and updates the circuit file accordingly. In order to avoid conflicting definitions, it is required in this case that CGS, GDS and G be assigned numeric values directly, which means that their values cannot be assigned through labels.

4.3 MODR BLOCK

As an alternative to a MODL block, a MODR block can be defined which implements the Microwave Harmonica FET model. The schematic of this model has been described in Section 3.2. The MODR block is similarly structured as the MODL block:

```
MODR

   [label definitions]

   [DC parameter definition]

   small-signal parameter definitions

END
```

4.3.1 DC PARAMETERS IN THE MODR BLOCK

Similarly to the MODL block, DC parameter definition in the MODR block must begin with the keyword "DC". The generic form is as follows.

```
    DC  IDSS=x1  GAMA=x2  VPO=x3  K1=x4  SL=x5  [IGO=x6]
 +      [IBO=x7]  [AFAG=x8]  [AFAB=x9]  [C10=x10]
```

where

DC	-->	keyword indicating the declaration of DC parameters
IDSS,...,C10	-->	large-signal model parameters
x1,...x10	-->	assigned values

The parameters may appear in any order.

Since the line is likely to be longer than 80 characters, one or more continuation lines may be used. The plus sign at the beginning of the second line, as shown above, indicates the presence of a continuation line.

The definition of DC parameters in the MODR block is optional. Without the DC definition, RoMPE will perform only small-signal modeling.

If the DC definition is given, five of the parameters, namely IDSS, GAMA, VPO, K1 and SL are required to be initialized by non-zero values. The other parameters are optional with a default value of zero.

4.3.2 SMALL-SIGNAL PARAMETERS IN THE MODR BLOCK

The Microwave Harmonica small-signal equivalent circuit has 15 model parameters. They are defined as:

```
   label_name:  FET  C1=x1  GDS=x2  G=x3  RG=x4  RD=x5  R1=x6
+                    RS=x7  [LS=x8]  [LG=x9]  [LD=x10]  [CF=x11]
+                    [CDS=x12]  [TAU=x13]  [F=x14]  [GGS=x15]
```

where

label_name	-->	a valid label name identifying the small-signal equivalent circuit model at a particular (but as yet unspecified) bias point
FET	-->	keyword signifying a small-signal circuit model definition
C1, ..., GGS	-->	parameters in the Microwave Harmonica small-signal model
x1, ..., x15	-->	assigned parameter values

The small-signal parameters may appear in any order.

As many small-signal models as the number of different bias points must be defined, since in general the small-signal parameter values depend on the bias. Seven of the parameters, namely C1, GDS, G, RG, RD, R1 and RS are required. The other parameters are optional with a default value of zero.

4.3.3 FIXED AND OPTIMIZABLE PARAMETERS IN THE MODR BLOCK

All the model parameters may be optimized except for the transconductance rolloff frequency F and the parasitic conductance GGS which must remain at fixed values.

The parameter values can either be assigned directly, such as

```
FET  RG=?2.5?  CDS=?0.07PF?  ...
```

or indirectly using labels, like

```
RGM: ?2.5?   C2: ?0.07PF?  ...
        ...

FET  RG=RGM  CDS=C2  ...
```

One exceptional case arises when DC parameters are defined. In this case, three small signal parameters C1, GDS and G are defined implicitly through the values of the bias voltages and the DC parameters. RoMPE automatically calculates the values for these three parameters from the specified DC parameters and bias voltages, and updates the circuit file accordingly. In order to avoid conflicting definitions, it is required in this case that C1, GDS and G be assigned numeric values directly, which means that their values cannot be assigned through labels.

4.3.4 AN EXAMPLE OF MODR BLOCK

The example that follows illustrates the definition of a MODR block. It defines three small-signal equivalent circuits (labelled as BIAS1, BIAS2, and BIAS3), as well as the DC parameters. Notice the extensive use of labels for assigning parameter values.

```
*
* This is a sample MODR block
*
MODR
*
*  Label declarations are made here
*
   R0:2.E-6       F0:1000GHZ    TAU:?0.007NS?
   LS:?0.02NH?    LG:?0.01NH?   LD:?0.01NH?
   RGM:?1.E-5 1.5 5?   C2:?0.07PF?    C3:?0.04PF?
   RII:?1.E-5 1.5 5?   C5:?0.07PF?    C6:?0.04PF?
   RDD:?1.E-5 1.5 5?   C8:?0.07PF?    C9:?0.04PF?
   RSS:?1.E-5 1.5 5?
*
*  DC parameters are defined here
*
   DC   IDSS=?0.2A?   VPO=?-4.0V?  GAMA=?-0.2?  C10=?1PF? K1=?1.0V?
+       SL=?.166666667? IG0=0.5NA IB0=0.5NA  AFAG=20/V  AFAB=1/V
*
*  Three small-signal equivalent circuits
*
  BIAS1: FET RG=RGM RD=RDD R1=RII RS=RSS GDS=?1.539996E-3? LS=LS
+ C1=?918.9766E-15? CF=C2 CDS=C3 G=?.0801996? TAU=TAU LG=LG LD=LD
+ F=F0 GGS=R0
  BIAS2: FET RG=RGM RD=RDD R1=RII RS=RSS GDS=?3.964435E-3? LS=LS
+ C1=?595.8452E-15? CF=C5 CDS=C6 G=?.0519039? TAU=TAU LG=LG LD=LD
+ F=F0 GGS=R0
   BIAS3: FET RG=RGM RD=RDD R1=RII RS=RSS GDS=?3.788282E-3? LS=LS
+ C1=?492.414E-15? CF=C8 CDS=C9 G=?.0290428? TAU=TAU LG=LG LD=LD
+ F=F0 GGS=R0
*
END
```

4.4 DATA BLOCK

A DATA block must follow the MODL or MODR block in the circuit file. It specifies the bias data and provides the names of S-parameter data files.

The DATA block begins with the keyword "DATA" and ends with the keyword "END", as

```
DATA
   data declaration line
   data declaration line
       .
END
```

Each data declaration line specifies the measurement at one bias points. Therefore, the number of data declaration lines implies the number of different bias points, and it must be the same as the number of small-signal FET models defined in the MODL or MODR block. The generic form of a data declaration line is

```
label_name: [S=file_name]  [VGS=x1  VDS=x2  IDS=x3]  [IGS=x4]
```

where

label_name	-->	a valid label name identifying a distinct bias point and the corresponding set of measurement
S	-->	keyword signifying S-parameter data
file_name	-->	the name of an existing file in the current data directory which contains the measured S-parameter data for the given bias point
VGS, ..., IGS	-->	keywords identifying the bias data

The S-parameter data file specified by file_name is assumed to reside in the current data directory. The data directory by default is "DATA_F", but it can be changed through the Cdir command (see Chapter 5). The entry [S=file_name] is optional, and its omission would indicate that S-parameter data is not available for the particular bias point.

The bias measurement data accepted by RoMPE includes VDS, VGS, IDS and optionally IGS. Whether the bias data is optional or required depends on whether or not DC parameters are specified in the MODL or MODR block. If DC parameters are specified, then bias data is required, otherwise it is optional.

The following is an example of a DATA block.

```
DATA
   DAT1: S=SPAR1.DAT  VGS=0V      VDS=4V  IGS=0A  IDS=0.177A
   DAT2: S=SPAR2.DAT  VGS=-1.74V  VDS=4V  IGS=0A  IDS=0.092A
   DAT3: S=SPAR3.DAT  VGS=-3.1V   VDS=4V  IGS=0A  IDS=0.037A
END
```

4.5 S-PARAMETER DATA FILE

RoMPE accesses the measured S-parameter data through data files which are separate from the circuit file. The names of these data files are provided in the DATA block, and the files are assumed to reside in the current data directory (also see Section 4.4).

Each S-parameter data file contains the measured S-parameter data for one bias point. Therefore, the user needs to supply as many data files as the number of different bias points.

The S-parameter data file may contain comment lines which should begin with an asterisk "*". Blank lines are NOT allowed in data files. Each data line in the file has the form of

```
FREQ  MS11  AS11  MS21  AS21  MS12  AS12  MS22  AS22
```

where FREQ represents a frequency value, MS11 the magnitude of S_{11}, AS11 the angle (phase) of S_{11} in degrees, MS21 the magnitude of S_{21}, AS21 the angle of S_{21}, and so on.

The S-parameters must be entered in the order specified above, and the frequencies must be in *ascending* order. The angles (phase), namely AS11, AS21, AS12 and AS22, must be given in degrees. The magnitudes, namely MS11, MS21, MS12 and MS22, must NOT be given in DB. The limit on the total number of frequencies is given in Section 2.5.

An example of S-parameter data file:

```
* FILE: SPAR1.DAT
* SEPT. 30/88
* 4V VDS/0V VGS/177MA IDS
*                                S-PARAMETERS
*       MS11     AS11     MS21     AS21     MS12      AS12     MS22     AS22
  2GHZ 0.9546   -46.72   4.0405   145.54   0.0291    62.95   0.6010   -21.43
  3GHZ 0.9392   -66.98   3.6149   129.27   0.0388    52.47   0.5808   -32.82
  4GHZ 0.8944   -83.24   3.3323   118.50   0.0458    42.58   0.5718   -39.93
  5GHZ 0.8789   -97.95   2.9539   102.85   0.0507    33.91   0.5701   -48.94
  6GHZ 0.8598  -108.88   2.6428    95.28   0.0518    28.76   0.5808   -54.82
  7GHZ 0.8460  -120.97   2.2946    82.85   0.0517    18.44   0.5683   -63.42
  8GHZ 0.8388  -127.78   2.0989    78.94   0.0503    18.99   0.5845   -68.54
  9GHZ 0.8340  -137.66   1.9225    67.49   0.0505    12.84   0.5867   -75.58
 10GHZ 0.8350  -143.32   1.7984    58.95   0.0525    10.51   0.6089   -79.69
 11GHZ 0.8326  -149.51   1.5910    56.35   0.0499    12.37   0.6166   -83.21
 12GHZ 0.8326  -155.26   1.5106    46.49   0.0507     6.11   0.6360   -91.66
 13GHZ 0.8196  -161.01   1.3838    40.82   0.0473     8.76   0.6427   -93.39
 14GHZ 0.8301  -166.19   1.2945    34.54   0.0466     4.40   0.6633  -101.10
 15GHZ 0.8242  -172.00   1.1615    24.82   0.0442     3.98   0.6718  -106.42
 16GHZ 0.8332  -174.63   1.1335    23.98   0.0436     7.27   0.6845  -108.67
 17GHZ 0.8190  -179.96   0.9365    11.88   0.0408     5.08   0.7045  -113.75
 18GHZ 0.8394  -180.64   0.9688     8.12   0.0420     6.08   0.7098  -115.22
```

4.6 OPT BLOCK

An OPT block must follow the DATA block in the circuit file. It formulates the modeling optimization by matching each small-signal model specified in the MODL or MODR block with an appropriate set of measurement data specified in the DATA block.

The OPT block is structured as

```
OPT
   opt sub-block
   opt sub-block
      .
END
```

Each "opt sub-block" specifies the optimization formulation for one bias point. Therefore, there must be as many "opt sub-blocks" as the number of different bias points. The generic form of an "opt sub-block" is

```
model_label=data_label [freq_range] [weights]
                       [freq_range] [weights]
                       ...
                       [freq_range] [weights]
```

where

model_label	-->	a label defined in the MODL or MODR block which identifies a small-signal FET model
data_label	-->	a label defined in the DATA block which identifies a set of measurement data
freq_range	-->	a valid frequency range
weights	-->	weights for optimization

4.6.1 MATCHING MODELS TO MEASUREMENTS

Each "opt sub-block" is led by the expression

```
model_label=data_label
```

where model_label must have already been defined in the MODL or MODR block as the identifier of a small-signal FET model, and data_label must have been defined in the DATA block as the identifier of a set of measurement. This expression directs RoMPE to match the small-signal FET model identified by model_label to the set of measurement data identified by data_label.

Each FET model label defined in the MODL or MODR block and each measurement data label defined in the DATA block must be referred to in the OPT block once and only once.

4.6.2 SPECIFYING THE FREQUENCY RANGE

The frequency range for each bias point is automatically determined by RoMPE from the corresponding S-parameter data file. For example, if the first frequency in the data file is 2GHZ and the last one 18GHZ, then the range is from 2GHZ to 18GHZ. Each bias point has an associated frequency range, and different bias points can have different frequency ranges.

For RoMPE's simulation-and-display option (see Chapter 5), each small-signal model is simulated in the corresponding frequency range and over the full range, i.e., every frequency in that range is used.

For optimization, it may be desirable to optimize the model over a sub-range of frequencies. This can be specified as

```
model_label=data_label F=low_freq [high_freq]
```

Omitting high_freq implies that the range contains a single frequency.

For example, using

```
BIAS1=DAT1 F=2GHZ 10GHZ
```

to direct RoMPE to match model BIAS1 to measurement set DAT1 in the frequency range from 2GHZ to 10GHZ.

More than one sub-range may be specified. For example,

```
BIAS1=DAT1  F=2GHZ  10GHZ
            F=15GHZ
            F=20GHZ 25GHZ
```

specifies three sub-ranges, the first one from 2GHZ to 10GHZ, the second one being a single frequency, namely 15GHZ, and the third one from 20GHZ to 25GHZ.

The frequency sub-range(s) must fall within the full range implied by the S-parameter data file, for an obvious reason. If no frequency sub-range is specified for a bias point, the full range will be used.

4.6.3 SPECIFYING THE WEIGHTS

Weights (weighting factors) can be specified for each bias point ("opt sub-block") and each frequency sub-range as

```
[WS=ws1 ws2 ws3 ws4 ws5 ws6 ws7 ws8] [WDC=wdc1 wdc2]
```

where

WS	-->	keyword signifying the weights for S-parameters
ws1, ..., ws8	-->	weights for MS11, AS11, MS21, AS21, MS12, AS12, MS22 and AS22, respectively. They must be entered in exactly this order
WDC	-->	keyword signifying the weights for DC data
wdc1, wdc2	-->	weights for IGS and IDS, respectively

The default is unit weight, i.e., all weights are set to 1.

Example:

```
BIAS1=DATA1  F= 2GHZ 10GHZ  WS=1 1 1 1 1 1 1 1  WDC=0 100
             F=11GHZ 18GHZ  WS=5 5 5 5 5 5 5 5
BIAS2=DATA2  WS=2 2 1 1 1 1 2 2  WDC=1.E-5 50
```

The example illustrates different weight assignment to different bias points and different frequency ranges.

Weights are used to emphasize and de-emphasize the relative importance of different responses. A larger weight attaches a greater importance to the response associated with the weight, and vice versa. However, the use of weights should never be abused.

CHAPTER 5

OPERATION

5.1 OVERVIEW OF MENU OPTIONS

This chapter describes the various options RoMPE offers through an extremely user-friendly command menu. The completely menu-driven operation of RoMPE is very easy to learn.

A menu of available options is always found in the menu window at the bottom of the screen display. Upon entering RoMPE, the program displays the top-level menu which consists of eight options. The user select an option by

- typing the first letter of the desired option. For example, type "r" or "R" to select the **Read** option, or, alternatively, by

- using the cursor left/right keys to move the cursor to the desired the option, and then pressing the <ENTER> key to select it.

An overview of the various RoMPE menus and sub-menus is presented in Figure 5.1, followed by a detailed description of each option.

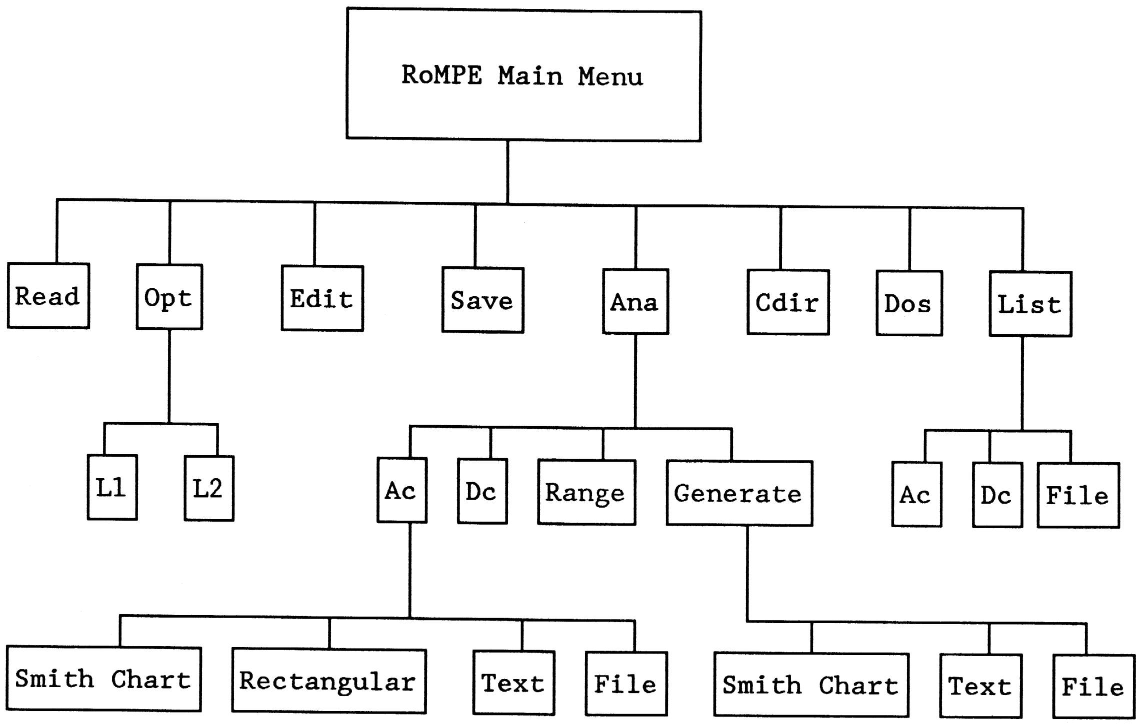


Fig. 5.1 Overview of menu options.

5.2 READING A FILE

To read a circuit file into RoMPE, select the **Read** command. When invoked, all files in the current data directory (see Section 5.7) are listed on the screen.

Choosing the desired file is done using the cursor control keys. Files selected by the action of these keys are highlighted. Pressing the <ENTER> key loads the file into RoMPE, at which point the contents of the file is displayed on the screen. At this point the circuit file can be edited, analyzed, optimized, or have a listing of its parameters generated.

5.3 SAVING FILES TO DISK

When a file is read, what really happens is that RoMPE makes an internal copy of the disk file. Changes to the file due to editing sessions or optimization are made only to the internal file, and will be lost unless the file is explicitly saved.

The menu option **Save** is used to save the current file to a disk file. The saved file may be given any valid DOS file name, with the default being the name of the last file read into RoMPE. The file may be saved to any directory by specifying a complete path name, the default being the current data directory (see Section 5.7).

5.4 SCREEN EDITOR

A full-screen editor CED.EXE is supplied with RoMPE. A copy of this editor should always reside in the same directory as ROMPE.EXE. The **Edit** option allows the user to edit the file that has been loaded into RoMPE via the **Read** command. The features of the screen editor are tabulated in Table 5.1.

TABLE 5.1 SUMMARY OF EDITOR FEATURES

Key	Editing Function
<F1>	**Quit:** leaves the editing mode, ignoring all changes made in the current editing session
<F2>	**Exit:** leaves the editing mode, retaining the changes
<F4>	**DelEOL:** deletes all text to the right of the cursor on the current text line
<F3>	**UndoF4:** restores text deleted by the last use of the <F4> (delete to EOL) key
<F6>	**DelLine:** deletes the current line of the file
<F5>	**UndoF6:** restores text deleted by the last use of the <F6> (delete line) key
Cursor keys	move the cursor in the indicated direction
Insert key	toggle insert/typeover modes
Backspace	deletes the character to the left
Delete key	deletes the character under the cursor
PgUp/PgDown	moves cursor up/down 15 lines of text
Home/End	moves cursor to the top/bottom left position on the screen
Enter key	inserts a blank line
Shift left/right	moves cursor to the previous/next word

5.5 SPAWNING DOS

The **Dos** command, when invoked, spawns a copy of the DOS command processor COMMAND.COM. This allows the user to temporarily leave RoMPE and enter the DOS environment. The DOS "EXIT" command will end the DOS session and return to RoMPE.

5.6 LISTING CIRCUIT PARAMETERS

The **List** menu option generates a listing of the current values of the DC and/or small-signal model parameters at all specified bias points. Undeclared parameters are assigned default values of 0. Since the screen can only show parameters for a maximum of three small-signal models (circuits) at a time, if there are more than three circuits the <ESC> and <ENTER> keys can be used to view the parameters that are not displayed.

The parameter value listing may also be directed to an ASCII file by pressing the <P> key as indicated in the menu window. The user will be prompted for a file names. The default file names are ROMPE_AC.LST and ROMPE_DC.LST, containing the small-signal and DC parameters, respectively.

5.7 CHANGING THE DATA DIRECTORY

RoMPE assumes all the circuit files and data files to reside in a designated data directory. The default is the "DATA_F" directory. The **Cdir** command allows the user to change this data directory to any other valid path.

5.8 ANALYZING THE CIRCUIT

The FET model(s) defined the circuit file can be analyzed using the **Ana** command. Once selected, a RoMPE.Ana second-level menu will replace the main menu in the screen window. Four options are provided in the RoMPE.Ana menu: **Ac**, **Dc**, **Range** and **Generate**.

5.8.1 AC ANALYSIS

Selection of the **Ac** option activates the RoMPE.Ana.Ac menu which offers six options: **Previous, Next, Smith-Chart, Rectangular, Text** and **File**. Entry into this submenu invokes the ac simulator on the first (or only) small-signal model in the circuit file. The resulting simulation is displayed graphically in a rectangular format. The RoMPE.Ana.Ac submenu is displayed in the menu window at the bottom of the screen.

The **Rectangular** format consists of eight plots of the small-signal model, representing the magnitude and phase of each S-parameter plotted with respect to frequency. All eight S-parameter plots corresponding to a given model (bias point) are displayed on the screen at once, with each plot showing both the target response of the measured data (light blue curve) and the calculated response of the model (red curve).

Viewing the target and calculated response in a rectangular display is useful for examining relative differences between the target response and calculated response. RoMPE adjusts the magnitude scale of each plot to so that the maximum and origin on the y axis are set by the maximum and minimum of the target (or calculated) responses. An example of a screen display at the entry into the RoMPE.Ana.Ac submenu is shown in Figure 5.2.

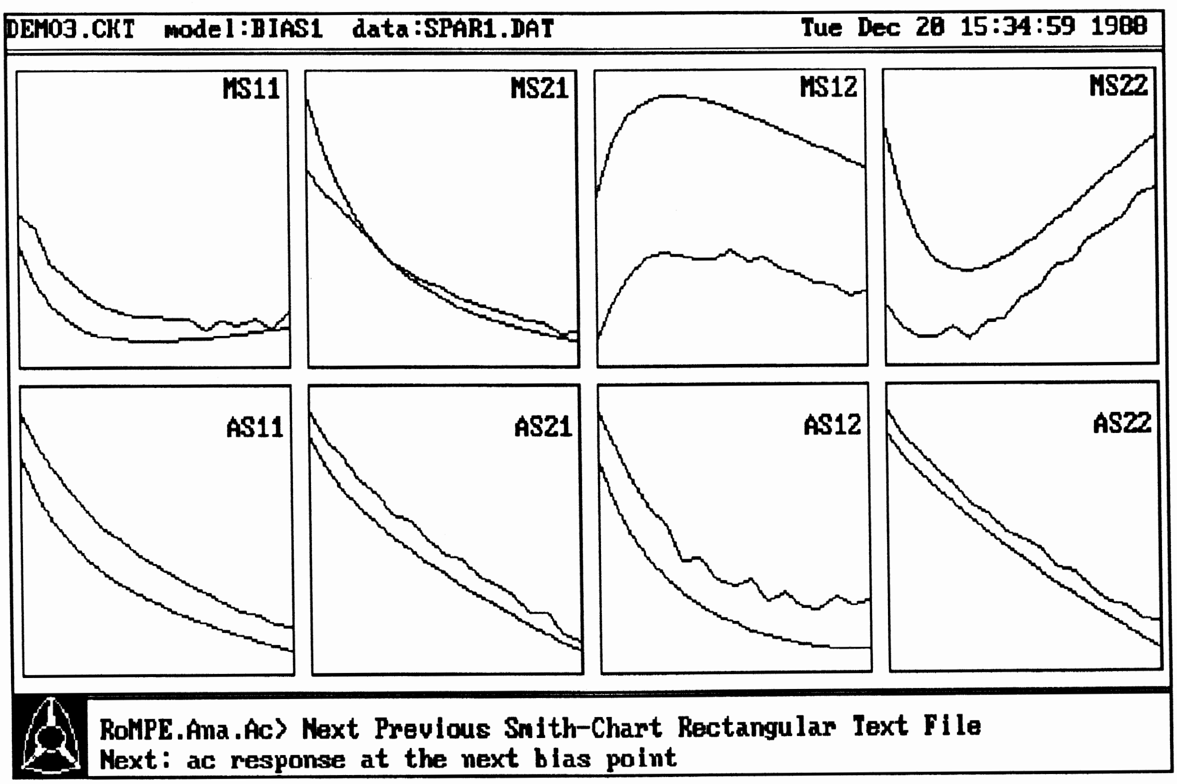


Fig. 5.2 Screen display after entering the RoMPE.Ana.Ac submenu.

The **Smith-Chart** option allows the user to view the target response and the model response for S11 or S22 on a Smith Chart. An illustration of the Smith Chart is shown in Figure 5.3. A small square box surrounds the S-parameter at the lowest frequency point. The magnitude of the reflection coefficient is shown at the bottom of the plot. To vary the magnification of the plot, specify a number between 1.0 and 5.0 when prompted. A magnification of 1 will display the entire Smith Chart.

Selecting the **Text** option displays the numeric values of the calculated S-parameters on the screen. These values can be sent to an ascii file by selecting the **File** option.

The **Previous** and **Next** menu items allow the user to view the results of the ac analysis at other bias points in the file.

To return to the RoMPE.Ana.Ac submenu, use <ESC> key.

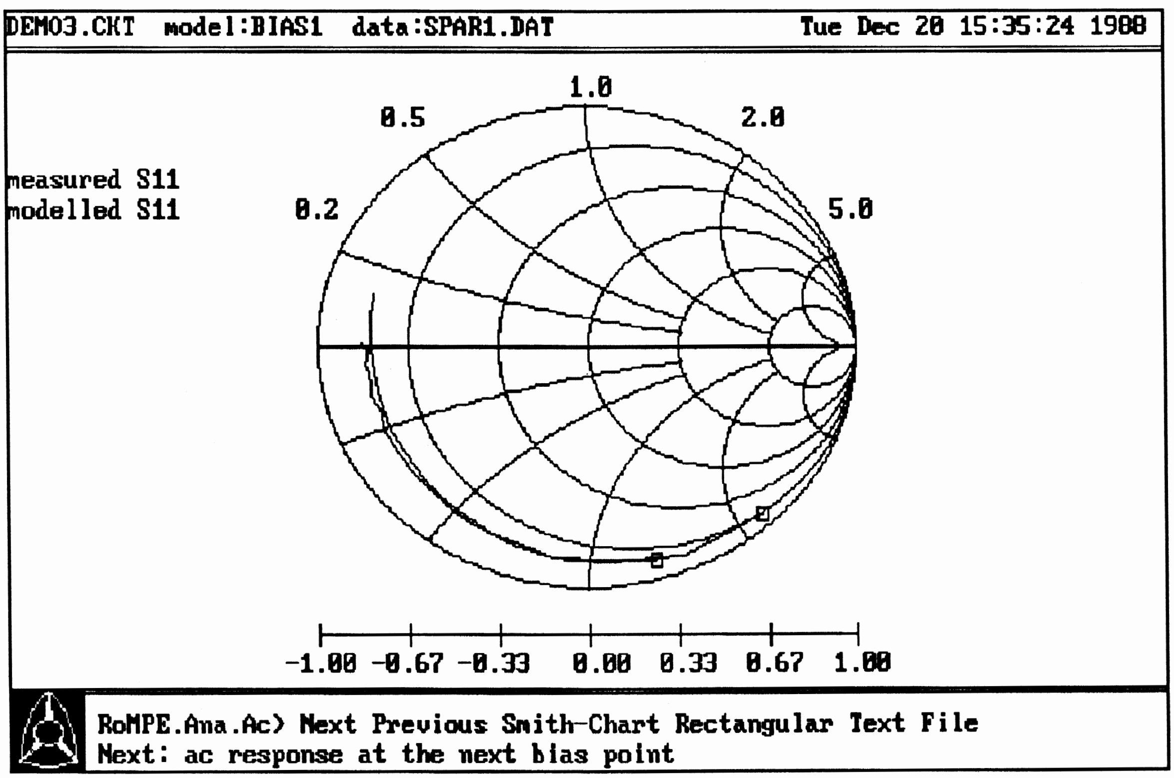


Fig. 5.3 Screen display of a Smith Chart plot.

5.8.2 DC ANALYSIS

Selecting the **Dc** option provides a DC simulation of the circuit based upon the DC parameters and bias point(s) specified in the circuit file. Bias conditions (VDS, VGS, and IDS) must be provided in the DATA block to enable DC analysis.

The graphics display resulting from a DC analysis consists of a set of calculated IV curves. The measured bias data is superimposed on the plot as small blue crosses "+".

The space bar can be used to toggle between the graphics display and a numeric display of the calculated points from which the IV curves were drawn. An example of a screen display after a DC analysis is shown in Figure 5.4.

To return to the main menu, use the <ESC> key.

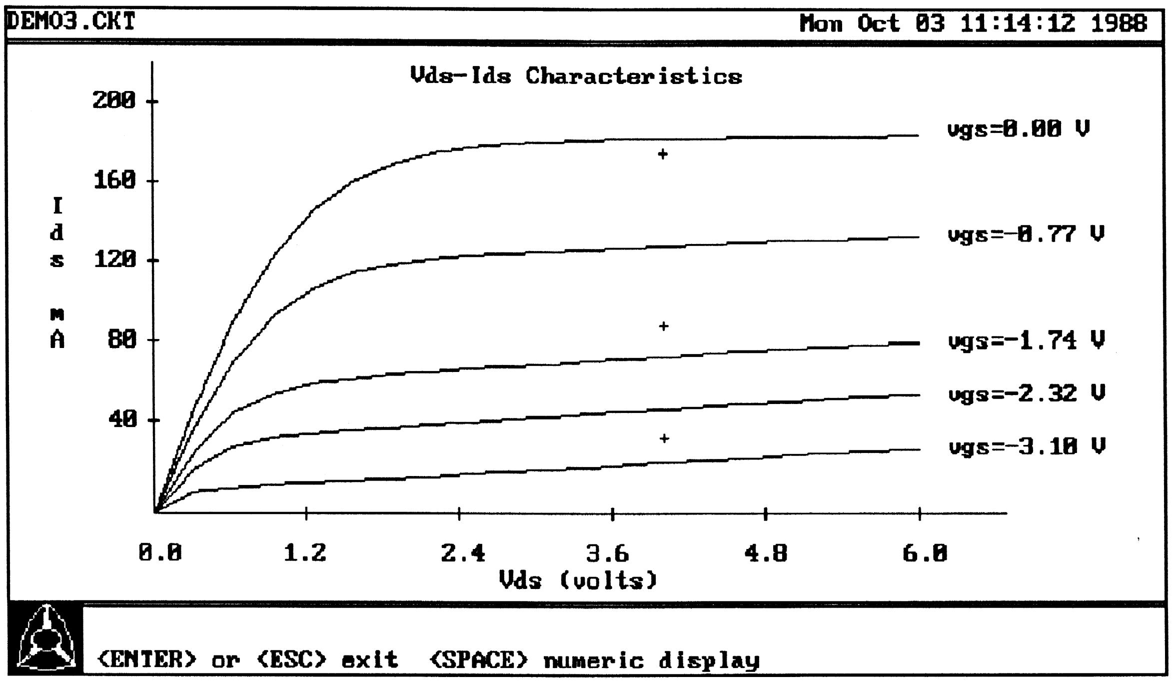


Fig. 5.4 Screen display after a DC analysis.

5.8.3 SETTING THE RANGE FOR DC ANALYSIS

Before a DC simulation can be performed, the user must provide a range of bias values over which the simulation will be performed. The **Range** option will prompt the user to specify the lowest and highest values desired for VDS, and the number of points. The more points chosen, the smoother the IV curve(s).

The user may also be required to choose the number of VGS points to be plotted, as directed by the prompts in the menu window. The range of VGS is automatically determined from the highest and the lowest VGS values given in the DATA block of the circuit file. The user is asked to specify the number of VGS points only if data for more than one bias point is provided in the circuit file. If only one bias point is given in the circuit file, then DC analysis is done at that one point.

Once a given range has been selected, that range will be the default for any subsequent DC analyses for the same circuit file. A new range can be defined using the **Range** option.

5.8.4 GENERATING S-PARAMETERS AT A SPECIFIED BIAS POINT

RoMPE V1.2 is now capable of generating S-parameters at user specified bias points for the FET model defined in the circuit file. RoMPE accomplishes this S-parameter simulation in a two step procedure which is transparent to the user. The first step of the procedure consists in obtaining the bias-dependent small-signal model parameter values at the user specified bias point either by interpolating the small-signal model parameter values of the bias points specified in the circuit file, or by using exact analytical expressions. Using these computed parameter values, the second step of the procedure consists in performing the small-signal S-parameter simulation.

The resulting S-parameters will be displayed in magnitude and phase format on screen, and can optionally be written to an ascii file. The components S11 and S22 can be displayed on a Smith Chart if desired.

If selected, the **Generate** option will prompt the user to specify values of VDS and VGS at the bias point of interest. It will then request the lowest and highest frequency values, together with the total number of frequency points. Up to 200 discrete frequency points may be specified.

The user is restricted to defining the VGS component of the bias point to within the maximum and minimum values of VGS bias data specified in the circuit file. This means that in order to utilize the **Generate** utility, the circuit file must contain bias data having at least 2 different values of VGS. There is no restriction to the range of VDS values chosen for the bias point.

5.9 OPTIMIZATION

The powerful modeling optimization feature of RoMPE can be activated through the **Opt** command. Selection of the **Opt** option brings up the RoMPE.Opt second-level menu. Two state-of-the-art gradient-based tools are available: an ℓ_1 (option **L1**) optimizer and a least squares ℓ_2 (option **L2**) optimizer.

Model parameters which have been designated as optimizable in the circuit file (delimited by a pair of question marks ?...?) will be optimized. During optimization, the match between the measured and the calculated S-parameters at the first bias point is graphically displayed and updated on the screen at each iteration. Figure 5.5 illustrates a typical screen display during optimization.

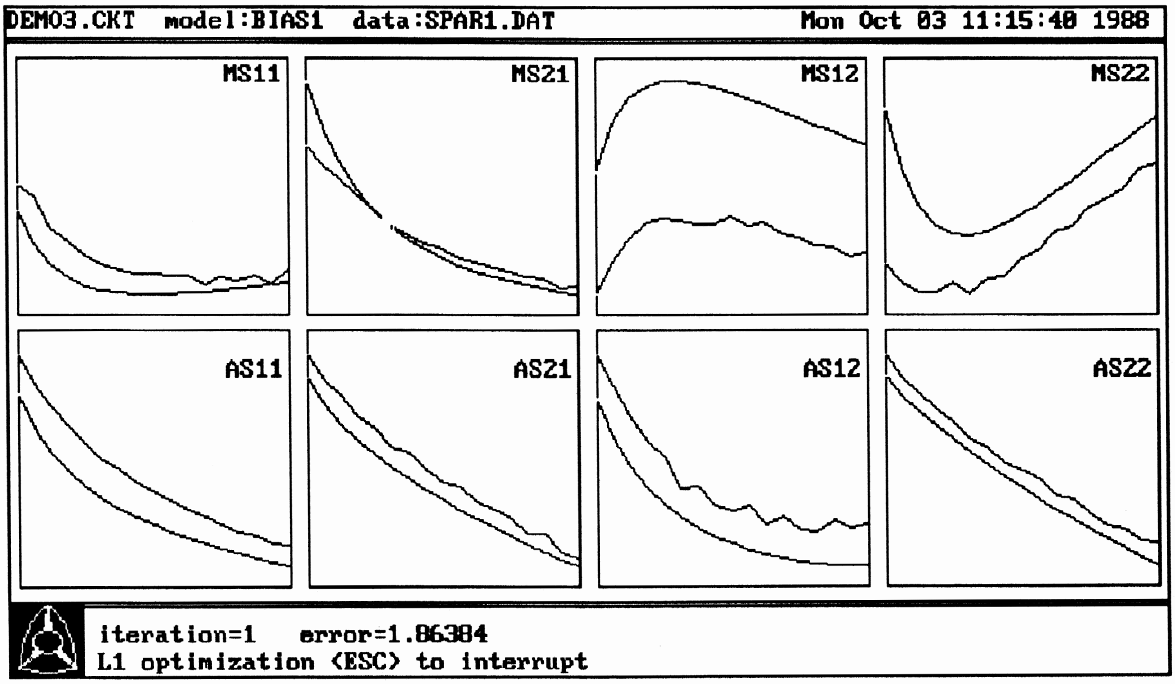


Fig. 5.5 Screen display during optimization.

Optimization terminates when either:

- no further reduction in the error function is possible, or,
- the user interrupts execution by pressing <ESC>. In this case, optimization can be resumed by pressing <ENTER>, or terminated by pressing <ESC>. It may take several seconds for an optimization interrupt request to be read and acknowledged by the optimizer.

In either case, the internal circuit file is updated with the optimized values. But, to keep a permanent copy of the optimized results, the **Save** command must be used explicitly.

During optimization, the program displays the match between the calculated and measured S-parameters on the screen, which will be updated at each iteration as the optimization progresses. If no S-parameter measurements are provided, the program will display and update the match between the measured and calculated DC bias points instead.

For the sake of clarity, the measured bias points appear on the screen connected by straight line segments. This does not imply that the whole curve is being optimized: only the discrete bias points are being used. Figure 5.6 shows a DC match display during optimization with twelve bias points.

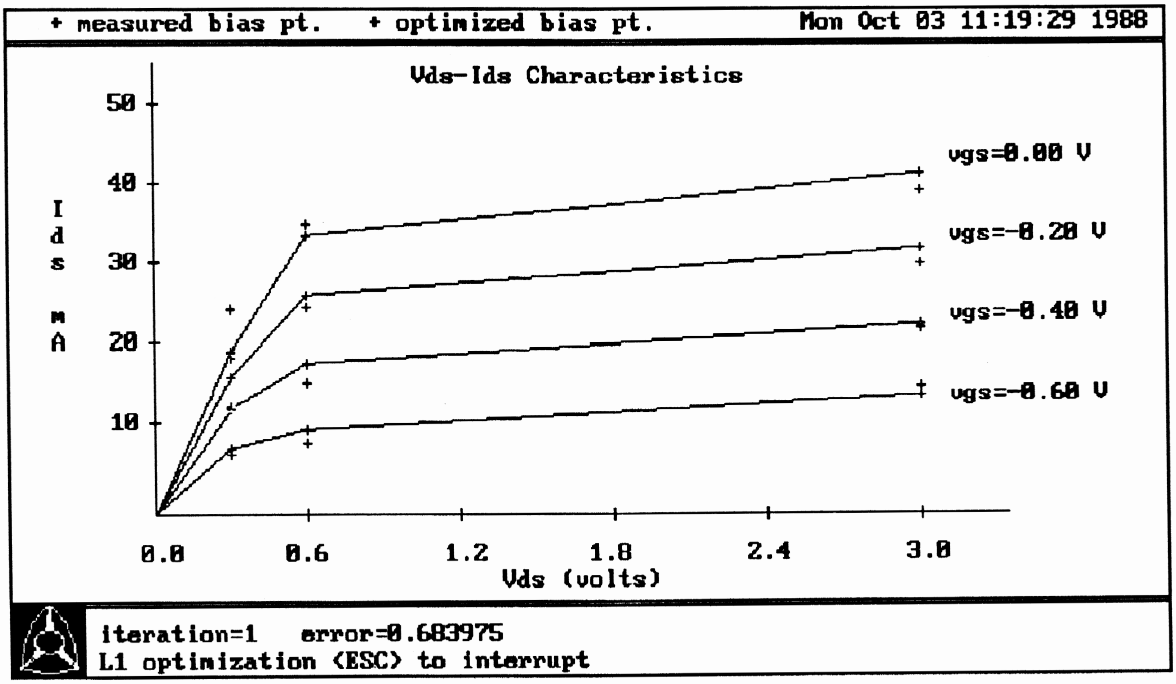


Fig. 5.6 Screen display of DC characteristics during optimization.

CHAPTER 6

A TYPICAL SESSION

The best way to learn is by actually doing. With this in mind, we present a sample RoMPE session which leads the user through the program and illustrates the use of its major features. The user is shown, step by step, how one might proceed through the program from beginning to end, with graphic displays provided at several points to illustrate the results of the actions taken.

This session helps users to familiarize themselves with RoMPE in a quick and painless fashion. It also serves as a quick review of the material presented in this Manual, and as a stand-alone demonstration of RoMPE features.

6.1 AN EXAMPLE: DEMO3.CKT

To run RoMPE, type **ROMPE** at the DOS system prompt. After a few seconds, the terminal will display the RoMPE title screen. At this point pressing any key will bring you into the main menu screen as shown in Figure 6.1.

The first operation is to read in a circuit file. The list of files in the data directory, which is in this case the default DATA_F directory, can be viewed by selecting the **Read** option, as shown in Figure 6.2. We select a menu option either by typing the first letter of the option, "r" or "R" for **Read**, or by moving the cursor to highlight the option and then pressing <ENTER>.

The file we need here is DEMO3.CKT. We move the cursor to highlight DEMO3.CKT in the directory list and then press <ENTER>. The file will now be loaded into RoMPE and displayed on the screen as shown in Figure 6.3.

The name of the circuit file presently resident in the program is printed in the top left corner of the screen. The entire contents of this file can be viewed by using the cursor up/down keys. If you wish to modify the file, the **Edit** command should be used.

Upon examination of this file we notice that it has specifications for three small-signal equivalent circuit models, identified by the labels BIAS1, BIAS2 and BIAS3 in the MODL block. The DC model parameters are also specified in the MODL block, and the DC bias data is given in the DATA block. This means that both DC and small-signal simulations can be performed.

To simulate the model, we select the **Ana** command from the main menu, which will lead us to the RoMPE.Ana second-level menu. We then may choose between an AC or DC simulation.

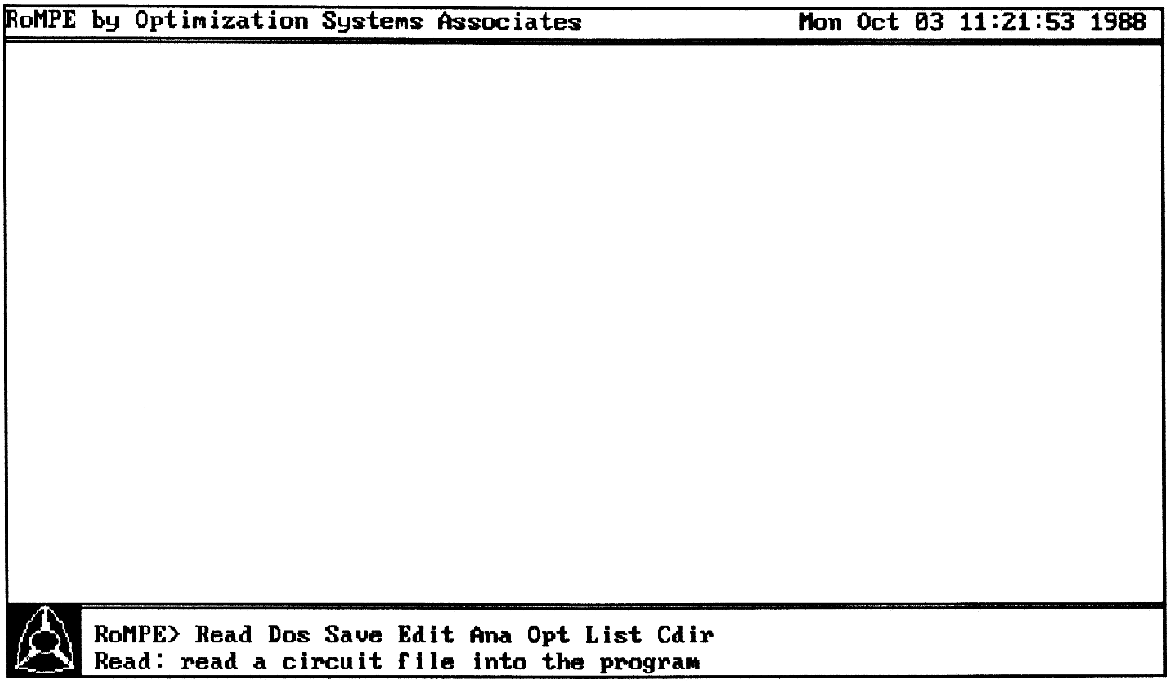


Fig. 6.1 Initial screen display.

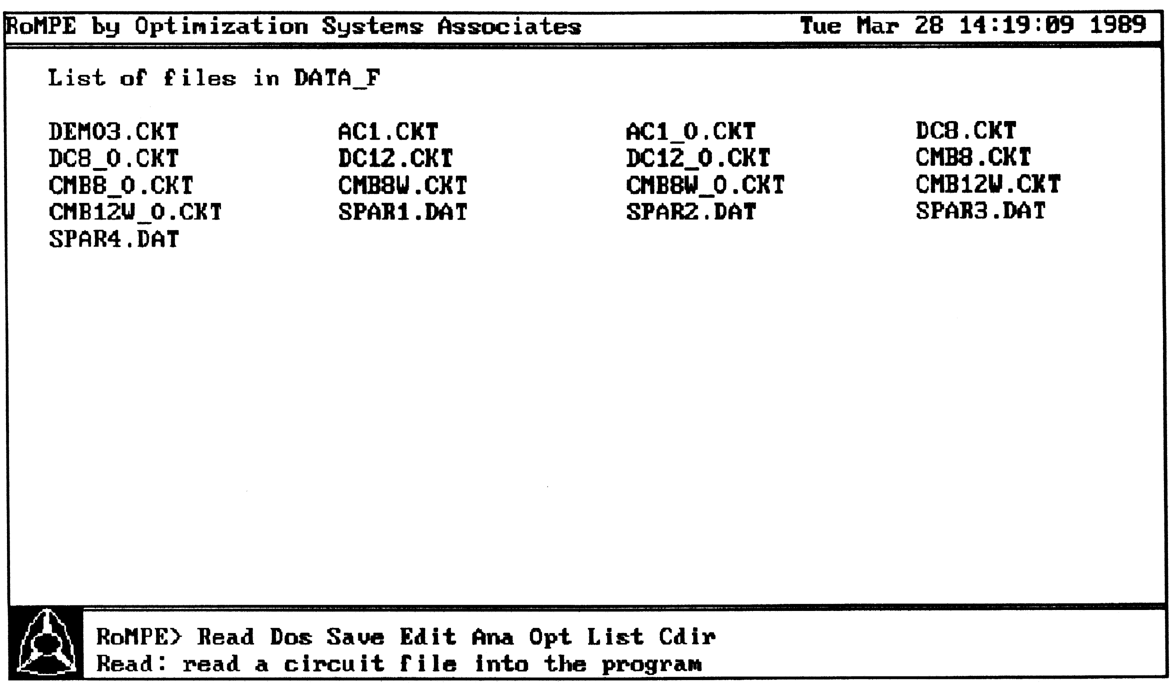
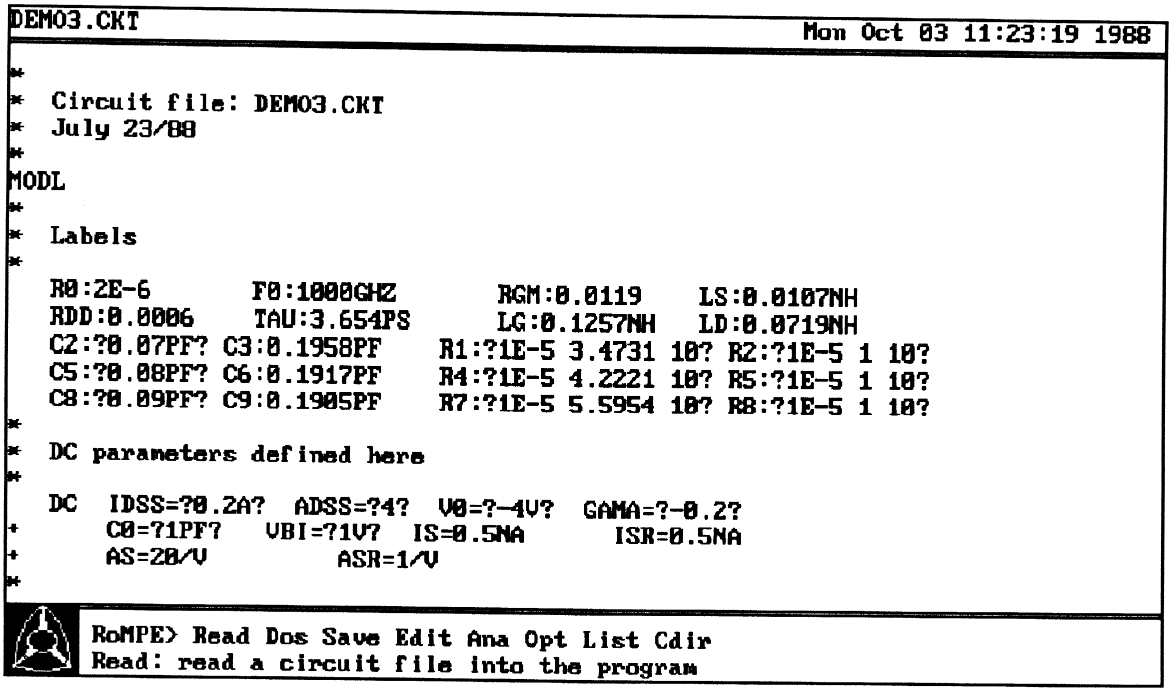


Fig. 6.2 Directory listing using **Read**.



```
DEMO3.CKT                                              Mon Oct 03 11:23:19 1988
*
*  Circuit file: DEMO3.CKT
*  July 23/88
*
MODL
*
*  Labels
*
   R0:2E-6        F0:1000GHZ        RGM:0.0119     LS:0.0107NH
   RDD:0.0006     TAU:3.654PS       LG:0.1257NH    LD:0.0719NH
   C2:?0.07PF? C3:0.1958PF     R1:?1E-5 3.4731 10? R2:?1E-5 1 10?
   C5:?0.08PF? C6:0.1917PF     R4:?1E-5 4.2221 10? R5:?1E-5 1 10?
   C8:?0.09PF? C9:0.1905PF     R7:?1E-5 5.5954 10? R8:?1E-5 1 10?
*
*  DC parameters defined here
*
   DC   IDSS=?0.2A?  ADSS=?4?  V0=?-4V?  GAMA=?-0.2?
+       C0=?1PF?   VBI=?1V?  IS=0.5NA       ISR=0.5NA
+       AS=20/V          ASR=1/V
*
RoMPE> Read Dos Save Edit Ana Opt List Cdir
Read: read a circuit file into the program
```

Fig. 6.3 DEMO3.CKT is loaded into RoMPE.

6.2 SMALL-SIGNAL (AC) SIMULATION

We first choose a small-signal (AC) simulation. Selecting the **Ac** option results in a graphical display of the eight S-parameters plotted against frequency for the first defined small-signal model ("BIAS1" from the circuit file), as shown in Figure 6.4.

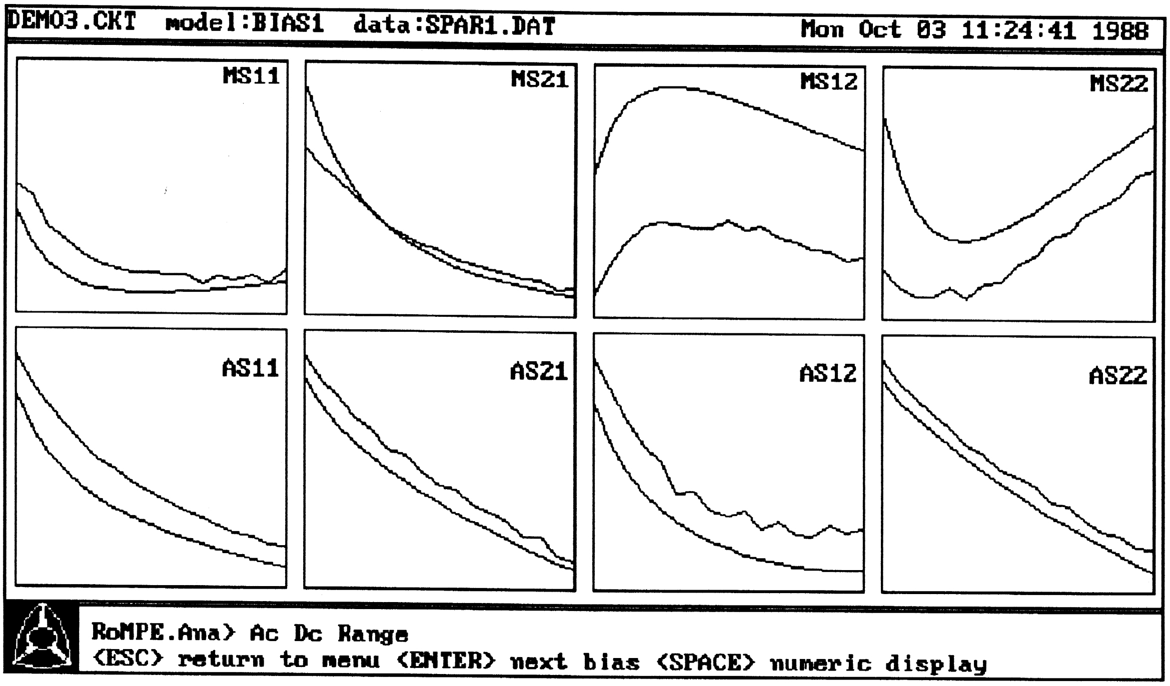


Fig. 6.4 S-parameter match for the first bias point.

Notice that each plot illustrates the match between the measured S-parameter data (which came from the file called SPAR1.DAT, as indicated at the top of the screen) and the calculated response of the model labelled "BIAS1". We can use the <ENTER> key to view the results of the other two small-signal models ("BIAS2" and "BIAS3"). We can also use the <SPACE> bar to toggle between the graphics display and the numeric display. To return to the RoMPE.Ana sub-menu, press <ESC> from the "BIAS1" screen display.

6.3 DC SIMULATION

Next, we select the **Dc** option from the RoMPE.Ana sub-menu. Since we have not yet set a range for DC analysis, the program will prompt us for the number of VGS curves to be generated, the range for VDS to be used in the simulation, and the number of points of VDS within its range. Smoother curves will be generated from more points, but it will take longer. In this case, we choose 6 VGS curves, a range from 0V to 10V for VDS and 16 points.

A few seconds after all the relevant information has been entered, a set of 6 I-V curves is displayed as shown in Figure 6.5. The small crosses on the plots are the 3 measured bias points given in the circuit file. Using the <SPACE> bar to toggle between the graphics and the numeric display. To the RoMPE.Ana sub-menu, press <ESC> or <ENTER>.

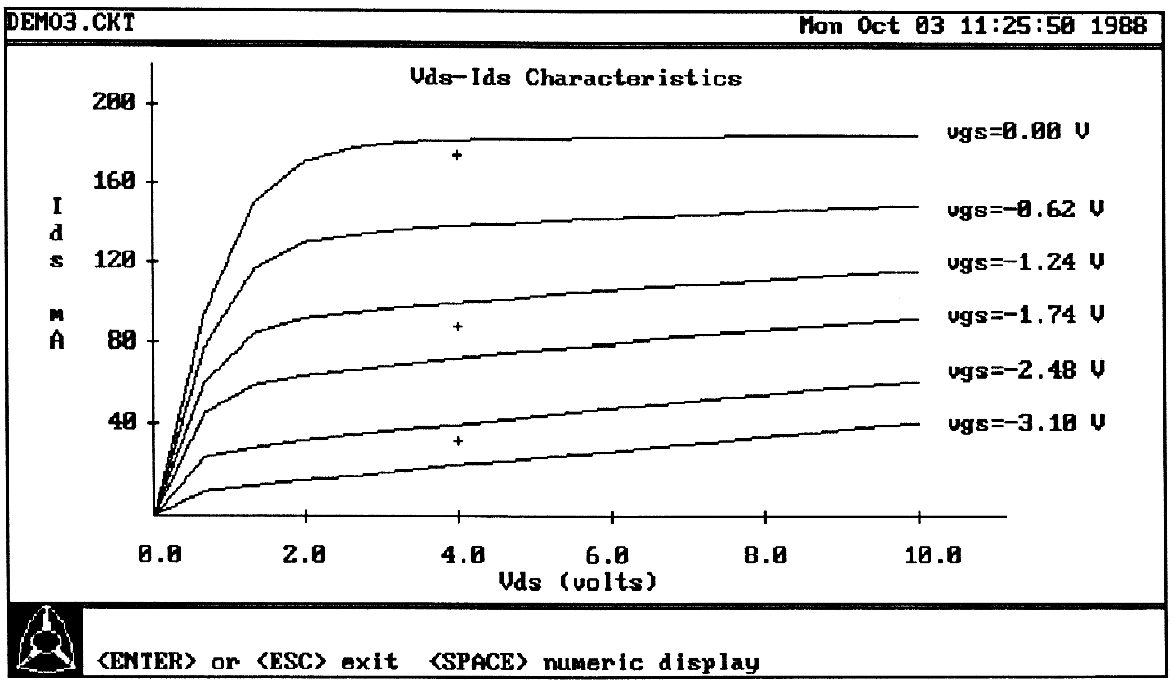


Fig. 6.5 DC match.

We can do another DC analysis but over a different range. First select the **Range** option to define a new range. This time, we select 3 VGS curves and a range of 0V to 5V for VDS. With this new range, the **Dc** option will generate the plot shown in Figure 6.6.

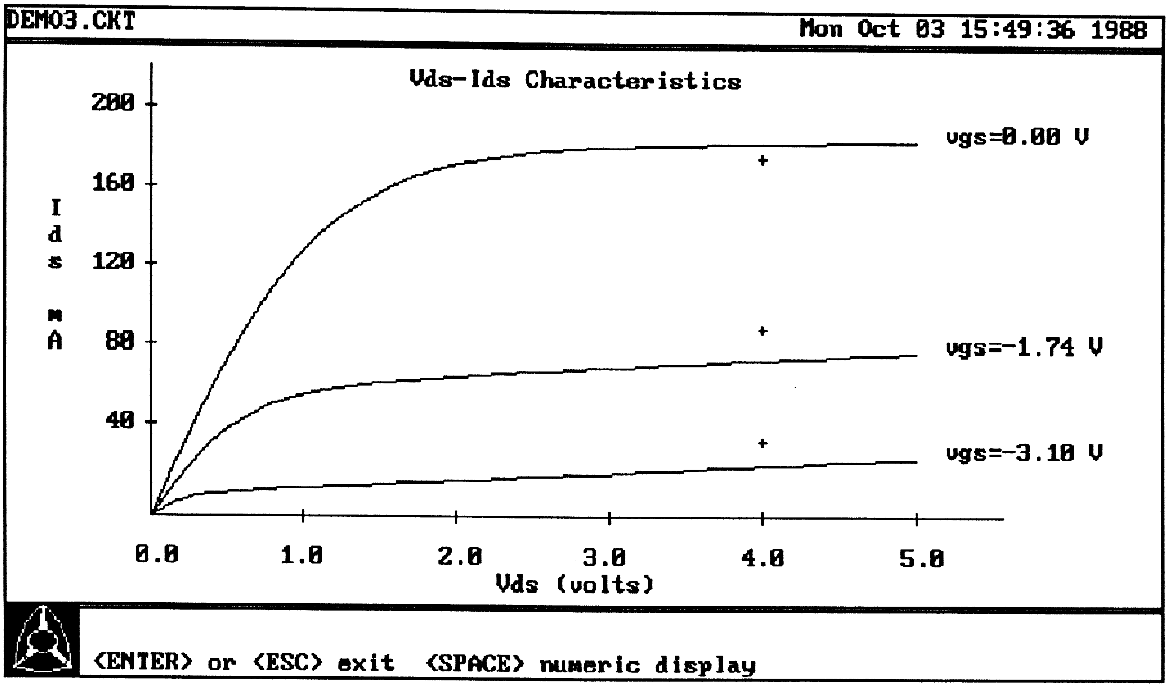


Fig. 6.6 DC analysis over a new range.

6.4 OPTIMIZATION

After analyzing the initial model, naturally we would like to optimize the model parameters. Press <ESC> key at the RoMPE.Ana menu to return to the main menu, and then select the **Opt** option. This leads us to the RoMPE.Opt sub-menu, which gives us the choice of two optimizers: ℓ_1 (option **L1**) and ℓ_2 (option **L2**). We will try **L1**.

During optimization, the eight S-parameter plots that we saw after the AC simulation will be displayed and updated at each iteration. Figure 6.7 shows the display at the first iteration of the ℓ_1 optimization. Notice that the iteration number and the current value of the error function are displayed in the menu window at the bottom of the screen. Optimization will continue until either the error function has reached a minimum or the user interrupts execution by pressing <ESC>.

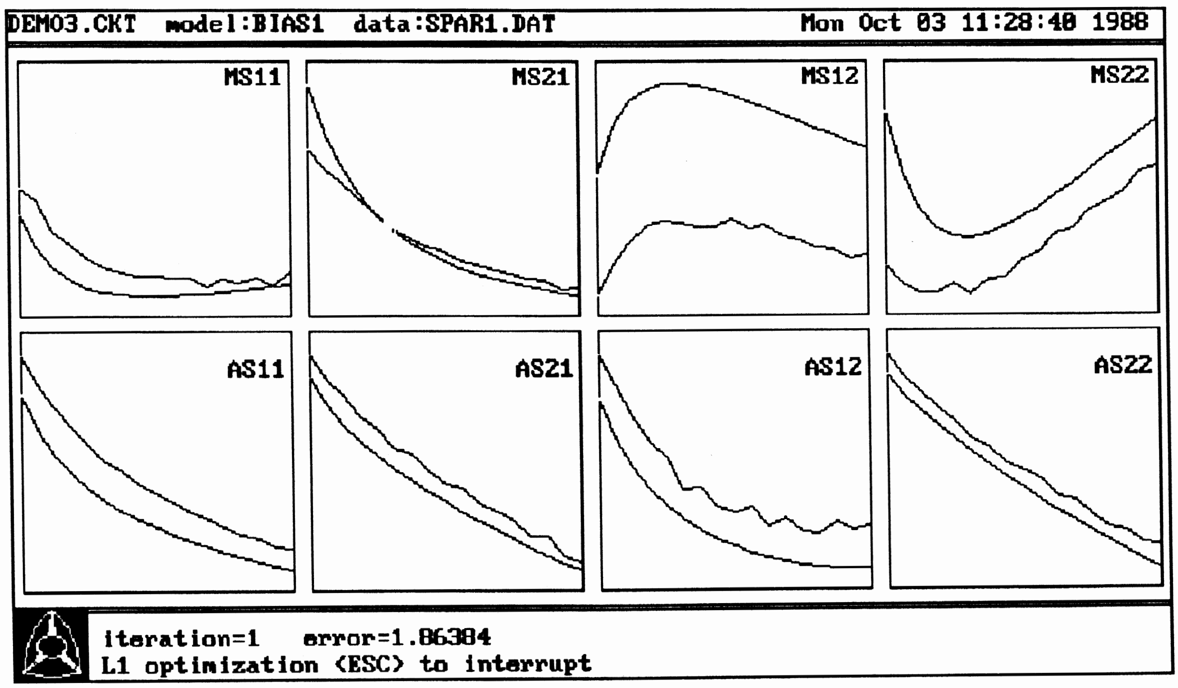


Fig. 6.7 S-parameter match after one iteration.

The optimization process can be interrupted by pressing the <ESC> key. When interrupted, RoMPE will offer the choice of terminating the optimization, resuming the optimization, or toggling the graphics displays.

Toggling the graphics displays between different bias points and/or AC/DC plots is a useful way of visually monitoring the optimization process. Figure 6.8 shows the result of interrupting the optimization and toggling to the DC plot.

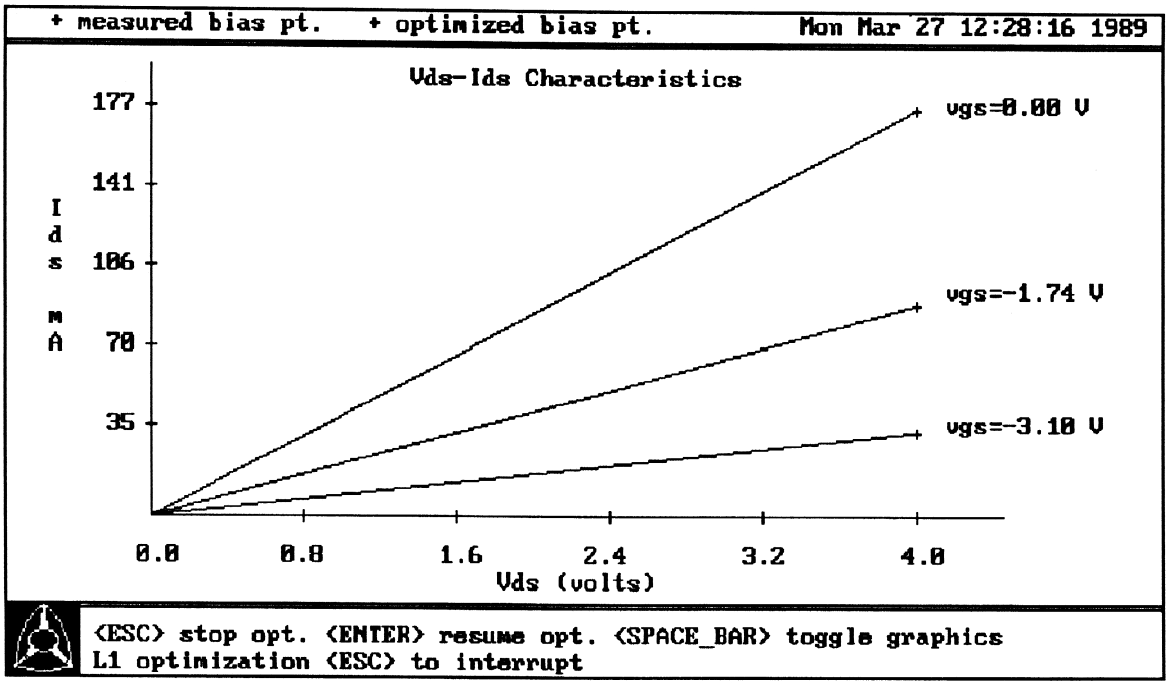


Fig. 6.8 DC match after two iterations.

If we let the optimization run its full course, we find that the process terminates after twelve iterations. At this point RoMPE indicates that it is updating the circuit file and then displays the updated file on the screen as it returns the program to the RoMPE.Opt sub-menu. We can return to the main menu by pressing <ESC>. Figure 6.9 illustrates the updated circuit file as it appears after optimization. Notice that all the optimizable parameter values in the MODL block have been automatically updated.

```
DEMO3.CKT                                                    Mon Mar 27 12:38:09 1989
*
*  Circuit file: DEMO3.CKT
*  July 23/88
*
MODL
*
*  Labels
*
   R0:2E-6          F0:1000GHZ          RGM:0.0119     LS:0.0107NH
   RDD:0.0006       TAU:3.654PS         LG:0.1257NH    LD:0.0719NH
   C2:?.0287591PF? C3:0.1958PF          R1:?1E-5 3.439099 10? R2:?1E-5 .5279671
+ 10?
   C5:?.0429747PF? C6:0.1917PF          R4:?1E-5 4.281962 10? R5:?1E-5 .3354569
+ 10?
   C8:?.0533481PF? C9:0.1905PF          R7:?1E-5 5.648626 10? R8:?1E-5 .221758
+ 10?
*
*  DC parameters defined here
*
   DC   IDSS=?.18883A?  ADSS=?3.047045?  V0=?-4.33569V?  GAMA=?-.3948963?

   RoMPE.Opt> L1 L2
   L1: modeling optimization using the L1 norm
```

Fig. 6.9 Updated circuit file after optimization.

6.5 SIMULATION OF THE OPTIMIZED MODEL

The optimized model can be simulated using the **Ana** option. The AC and DC matches shown in Figures 6.10 and 6.11 are clearly improved over those in Figures 6.4 and 6.6.

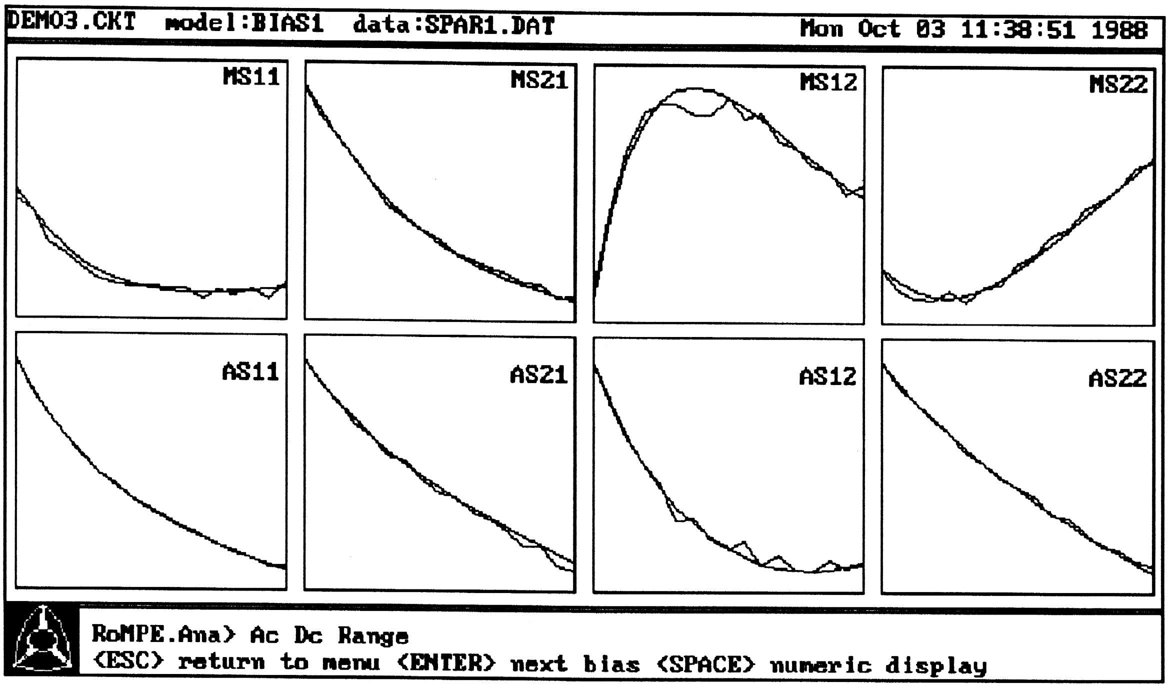


Fig. 6.10 S-parameter match for the first bias point after optimization.

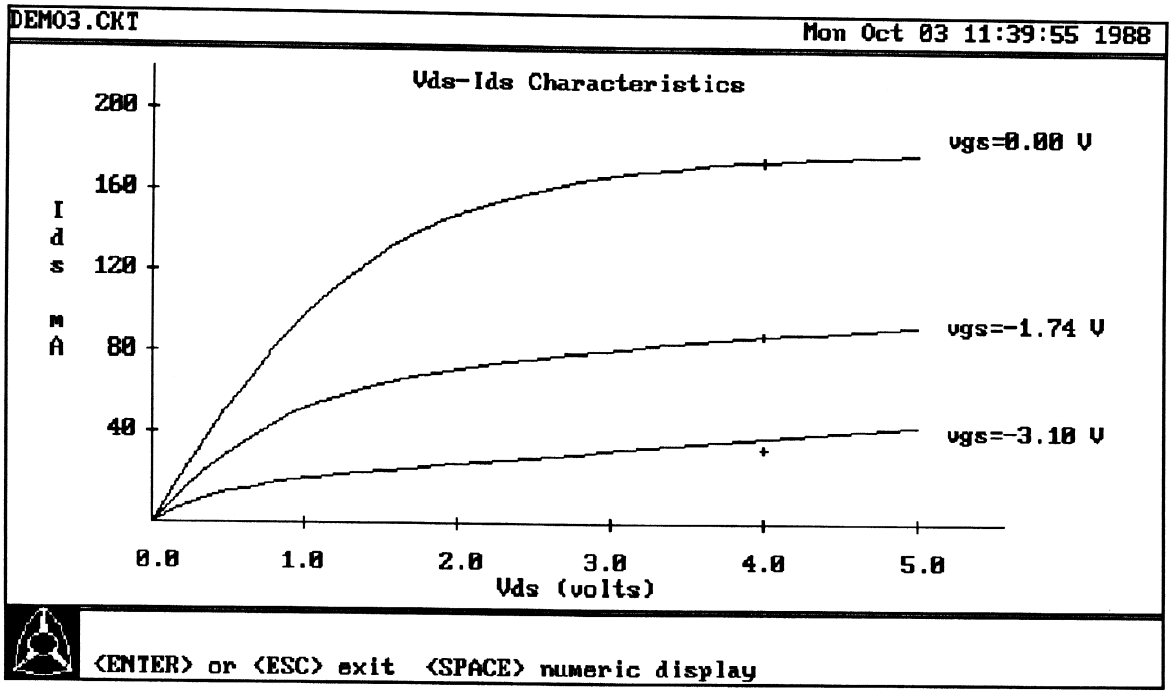


Fig. 6.11 DC match after optimization.

6.6 VIEWING THE CIRCUIT PARAMETERS

The **List** option in the main menu can be used to display the model parameters separately from the circuit file. Two options in the **List** menu, namely **Ac** and **Dc**, direct the AC and DC parameters to be generated and displayed, respectively.

The AC and DC parameter lists can also be directed to an output file by pressing the "p" or "P" key. Tables 6.1 and 6.2 show the contents of files ROMPE_AC.LST and ROMPE_DC.LST, which respectively contain the AC and DC model parameter lists.

TABLE 6.1 OUTPUT LIST OF SMALL-SIGNAL MODEL PARAMETERS

PARAMETER VALUES GENERATED FROM RoMPE FILE: DEMO3.CKT
RoMPE Small-Signal Model Parameters

	BIAS1	BIAS2	BIAS3
RG (OH)	0.0119	0.0119	0.0119
RD (OH)	0.0006	0.0006	0.0006
GDS (/OH)	0.004849	0.005758	0.006302
RI (OH)	3.439	4.282	5.649
RS (OH)	0.528	0.3355	0.2218
LS (NH)	0.0107	0.0107	0.0107
CGS (PF)	0.5947	0.3994	0.3331
CDG (PF)	0.02876	0.04297	0.05335
CDS (PF)	0.1958	0.1917	0.1905
G (/OH)	0.05708	0.04378	0.03023
T (PS)	3.654	3.654	3.654
LG (NH)	0.1257	0.1257	0.1257
LD (NH)	0.0719	0.0719	0.0719
F (GHZ)	1000	1000	1000
GGS (/OH)	2e-006	2e-006	2e-006

TABLE 6.2 OUTPUT LIST OF DC MODEL PARAMETERS

PARAMETER VALUES GENERATED FROM RoMPE FILE: DEMO3.CKT
RoMPE Large-Signal Model Parameters

IS (NA)	0.5
AS (/V)	20
ISR (NA)	0.5
ASR (/V)	1
IDSS(A)	0.1888
ADSS( )	3.047
VO (V)	-4.336
GAMA( )	-0.3949
CO (PF)	0.6159
VBI (V)	1.285

6.7 SAVING THE OPTIMIZED MODEL

After optimization, the circuit file appears to have been updated. Remember that it is only the working copy of the circuit file, but *not* the disk file that has been updated. In order to save the optimized results to a disk file, the **Save** command will have to be used explicitly. Once invoked, the program offers the choice of saving the file under a new name or updating (overwriting) the original circuit file.

Always remember to save optimized results explicitly, otherwise the results will be lost when you read in another file or exit from RoMPE.

6.8 EXIT FROM RoMPE

To exit from RoMPE, press <ESC>.

CHAPTER 7

A COMPREHENSIVE CASE STUDY

7.1 OVERVIEW

This chapter provides a comprehensive and instructive example of exploring the technical capabilities and flexibility of RoMPE.

The set of MESFET data used here is as follows:

1. A set of S-parameter measurements at 20 frequency points for the bias point VDS=3.0V, VGS=-0.4V and IDS=0.021A.

2. Bias data from DC I-V characteristics.

The bias data is given in Table 7.1. The S-parameter data file is SPAR4.DAT. You should be able to find this data file and all the circuit files referred to in this chapter in the DATA_F directory on the RoMPE floppy disk.

TABLE 7.1 DC BIAS DATA: IDS VALUES FOR VDS AND VGS

		VGS (V)			
		0.0	-0.2	-0.4	-0.6
VDS (V)	0.3	20.0 mA	17.0 mA	13.0 mA	8.0 mA
	0.6	34.3	26.8	18.5	10.3
	3.0	41.8	32.5	23.3	14.5

To extract model parameters from this set of data, several approaches are described and their results discussed. These approaches attack the problem from different angles and utilize different combinations of the data. A careful comparison of the results should provide some useful insight to the problem of parameter extraction in general, and the application of RoMPE in particular.

Tables 7.2 and 7.3 tabulates the initial guess of the small-signal and DC parameters, respectively.

TABLE 7.2 INITIAL AC PARAMETER VALUES

AC Parameter	Initial Value
LG	50.0PH
LD	50.0PH
LS	0.25PH
RG	2.5OH
RD	2.5OH
RS	1.5OH
RI	2.9OH
CGS	0.21PF
CDG	0.01PF
CDS	0.08PF
T	2.5PS
GDS	24.5/KOH
G	43.5/KOH
F	33GHZ
GGS	2.0/MOH

TABLE 7.3 INITIAL DC PARAMETER VALUES

DC Parameter	Initial Value
IDSS	0.042A
ADSS	3.0
V0	-1.0V
GAMA	-0.2
C0	0.2PF
VBI	0.8V
IS	0.5NA
AS	20.0/V
ISR	0.5NA
ASR	1.0/V
RG	1.5OH
RD	1.5OH
RS	1.5OH
RI	1.5OH

7.2 USING ONLY SMALL-SIGNAL S-PARAMETERS

Perhaps the simplest application of RoMPE is the conventional single-bias small-signal model parameter extraction. It requires only one set of S-parameter data and extracts only the small-signal parameters. Even in this case RoMPE is among the most efficient tools on the market, because it has the best optimizers and employs adjoint sensitivity analysis for gradient calculation.

The circuit file AC1.CKT sets up the problem. It contains neither DC parameter definition nor bias data.

The S-parameter match at the initial point is shown in Figure 7.1. The model after being optimized for 37 iterations exhibits a very good match as shown in Figure 7.2. The optimized result is saved in file AC1_O.CKT.

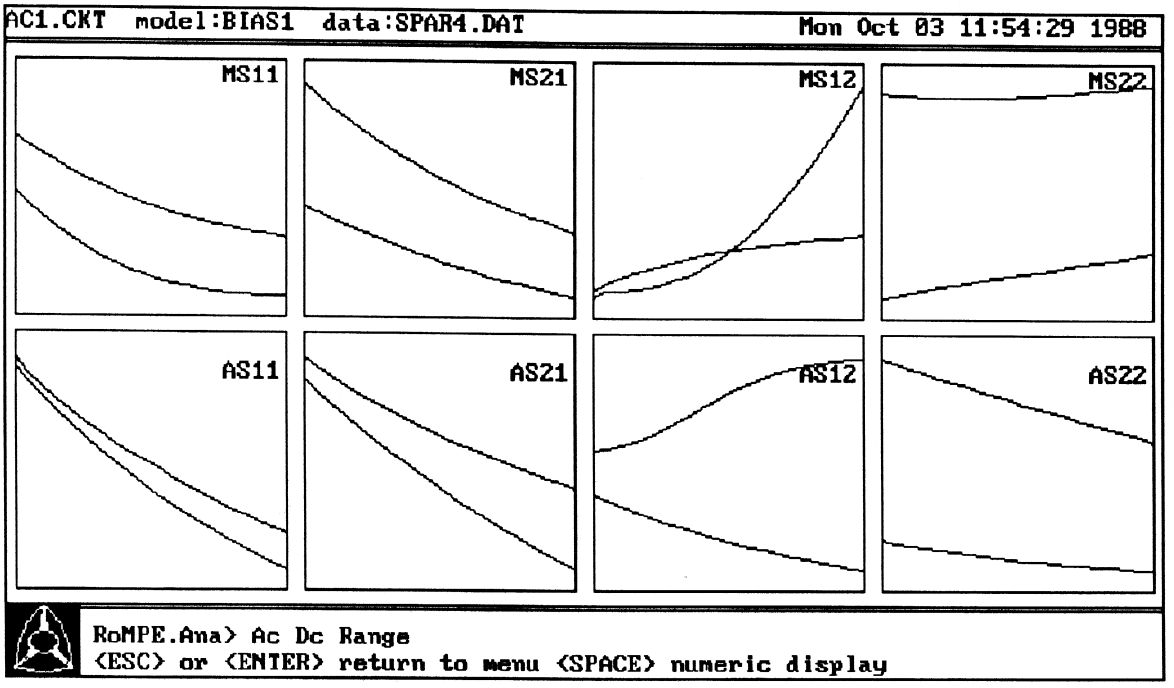


Fig. 7.1 Initial match for AC1.CKT.

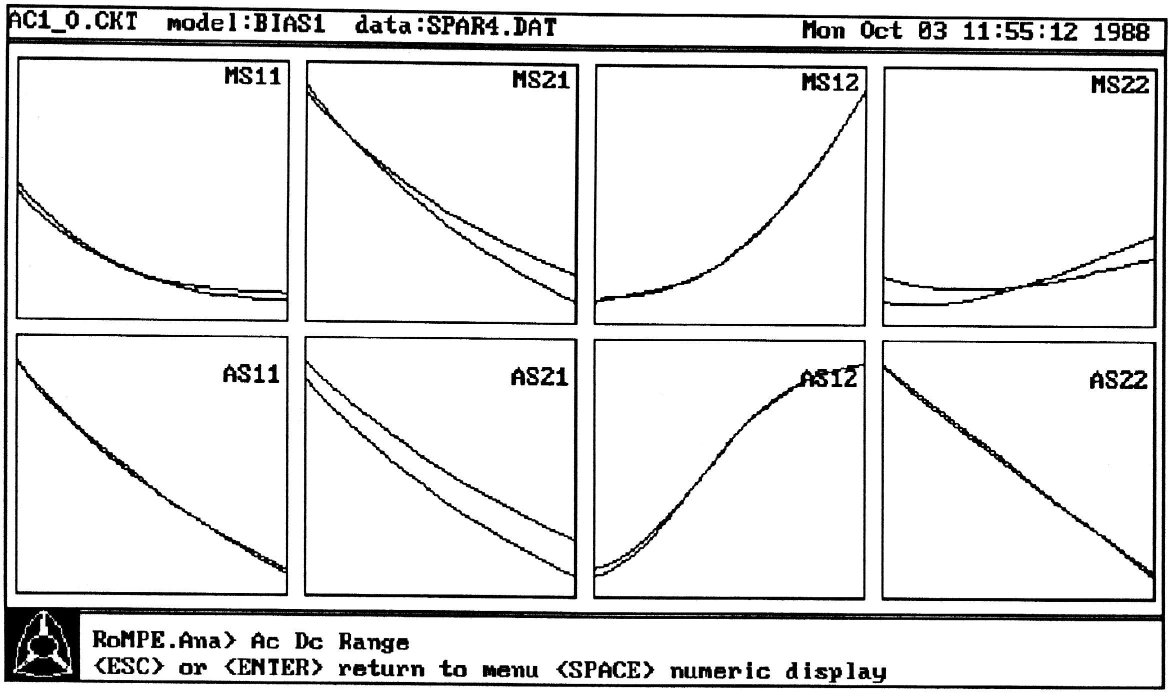


Fig. 7.2 Match for AC1_O.CKT.

7.3 DC CURVE FITTING

RoMPE can also be used to extract model parameters by attempting to fit the model DC response to a set of bias data. From the initial DC parameter values listed in Table 7.3, two different runs were performed. The circuit files are DC8.CKT and DC12.CKT, using 8 and 12 bias points, respectively. The DC curve-fitting plots for these results are shown in Figures 7.3 and 7.4, respectively. The optimized results are saved in files DC8_O.CKT and DC12_O.CKT, respectively.

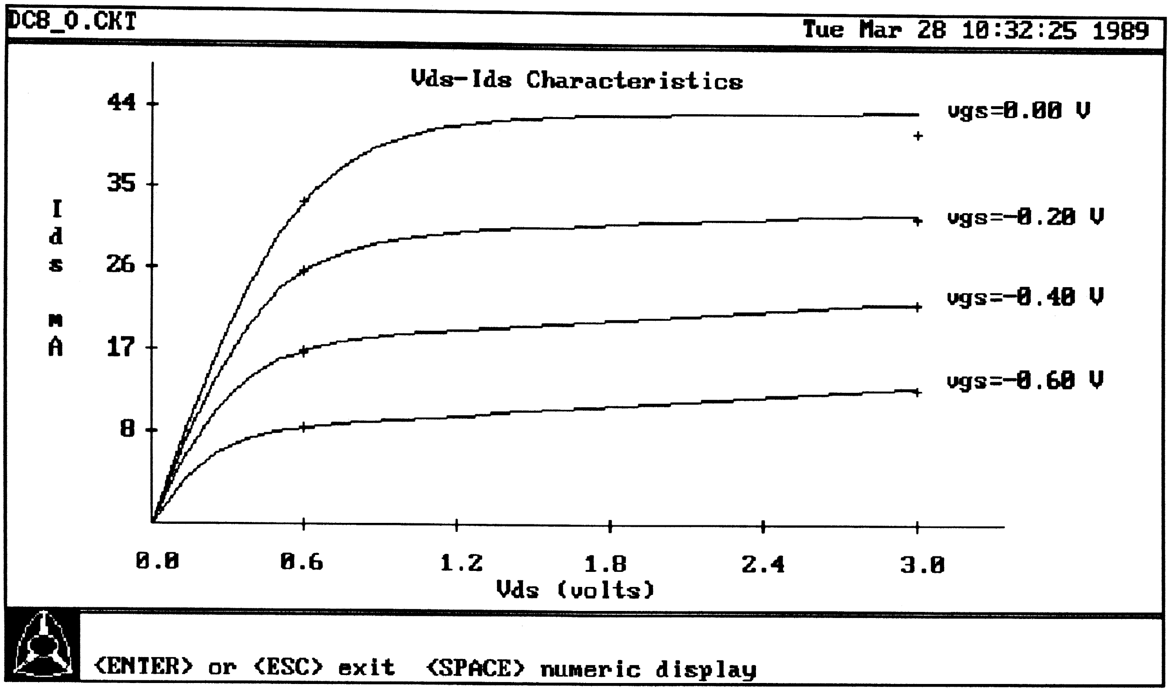


Fig. 7.3 DC match for DC8_O.CKT.

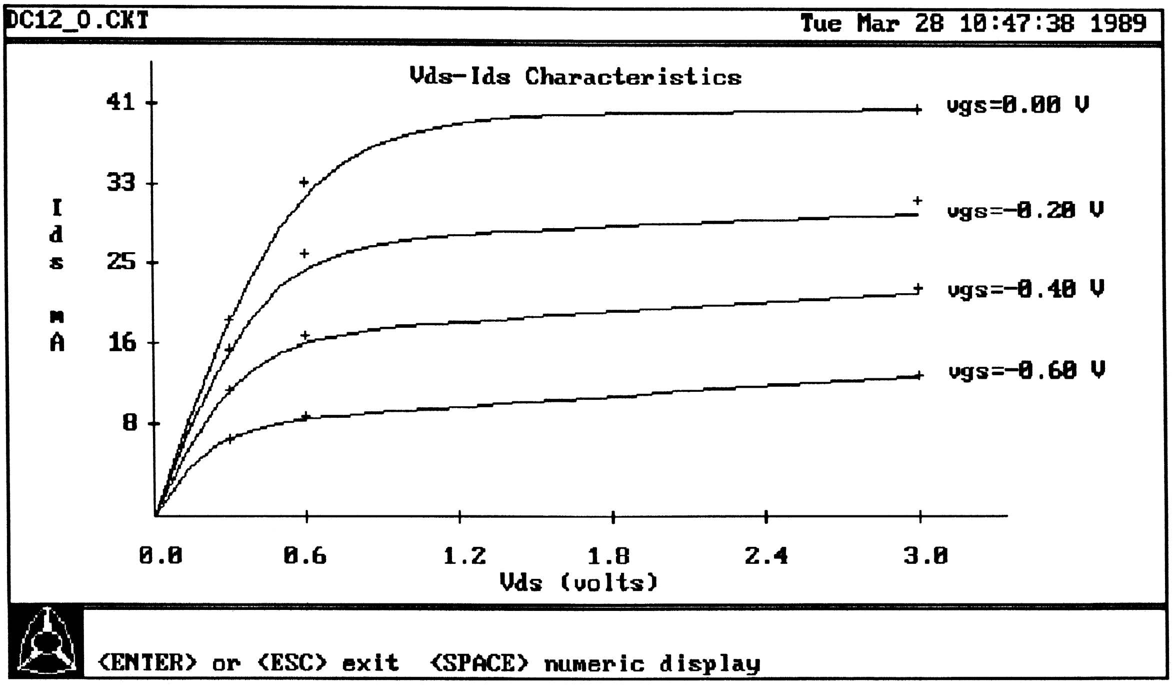


Fig. 7.4 DC match for DC12_O.CKT.

7.4 MIXING THE RESULTS OF AC AND DC EXTRACTION

Prior to RoMPE, the conventional approach to modeling consisted in the *separate* extraction of small-signal and DC parameters. The results were then simply mixed together in an attempt at "large-signal modeling".

To illustrate the inadequacy of this approach, we simply mix the optimized small-signal parameters from AC1_O.CKT with the optimized DC parameters from DC8_O.CKT to create the file CMB8.CKT. Figures 7.5 and 7.6 reveals that although *separately* the DC parameters generate a good DC match and the small-signal parameters generate a good S-parameter match, the simply "mixed" model is not useful. This experiment clearly confirms the need for *simultaneous* extraction of DC and small-signal parameters.

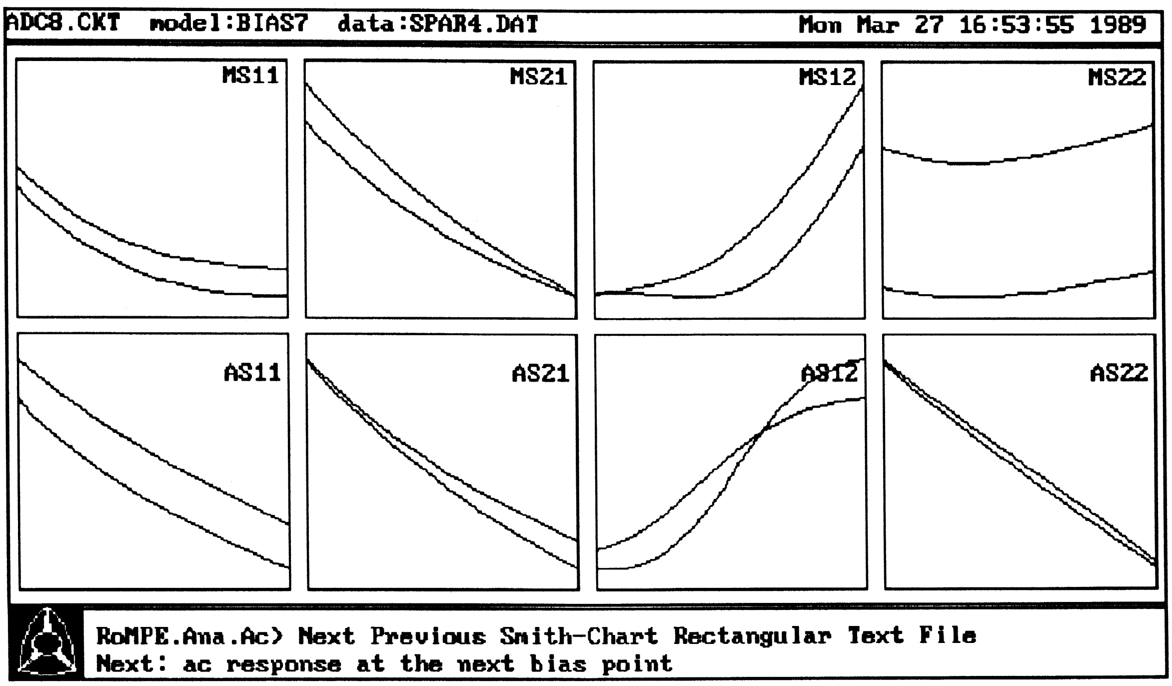


Fig. 7.5 S-parameter match for CMB8.CKT.

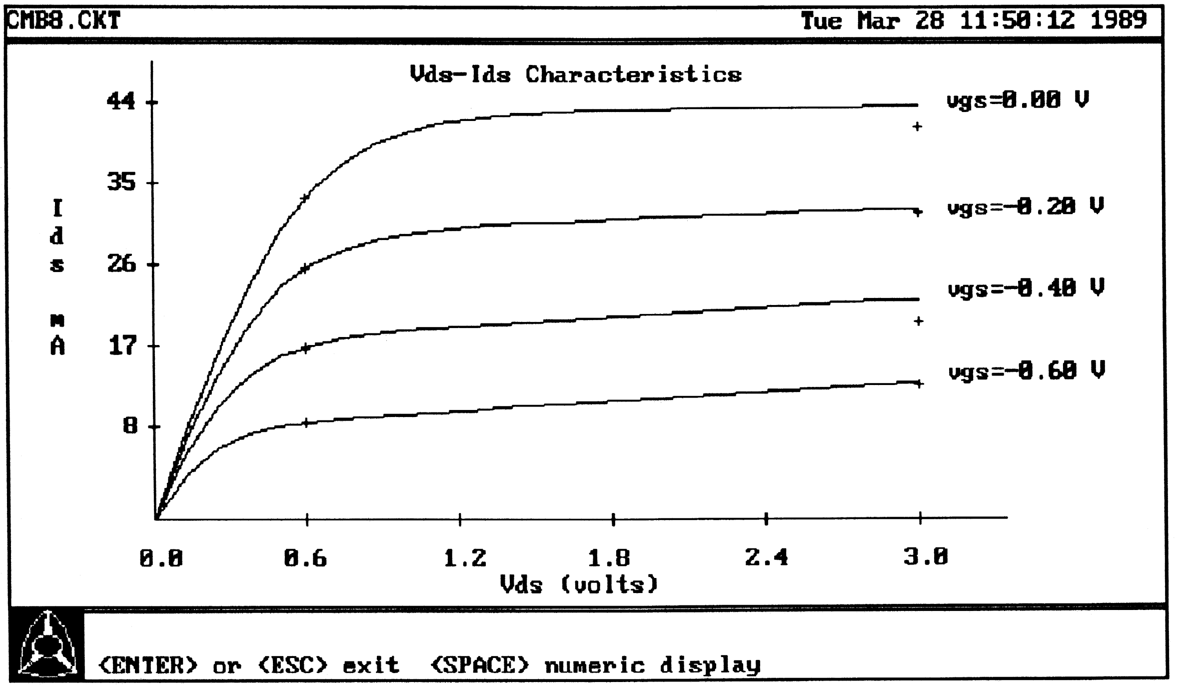


Fig. 7.6 DC match for CMB8.CKT.

7.5 SIMULTANEOUS AC AND DC PARAMETER EXTRACTION

The best approach, which is a unique feature offered by RoMPE, is to optimize the small-signal and DC parameters *simultaneously.* CMB8.CKT was used as the initial model in which both the DC and small-signal parameters were designated as optimizable. After optimization we achieved the match shown in Figures 7.7 and 7.8. The result is saved CMB8_O.CKT.

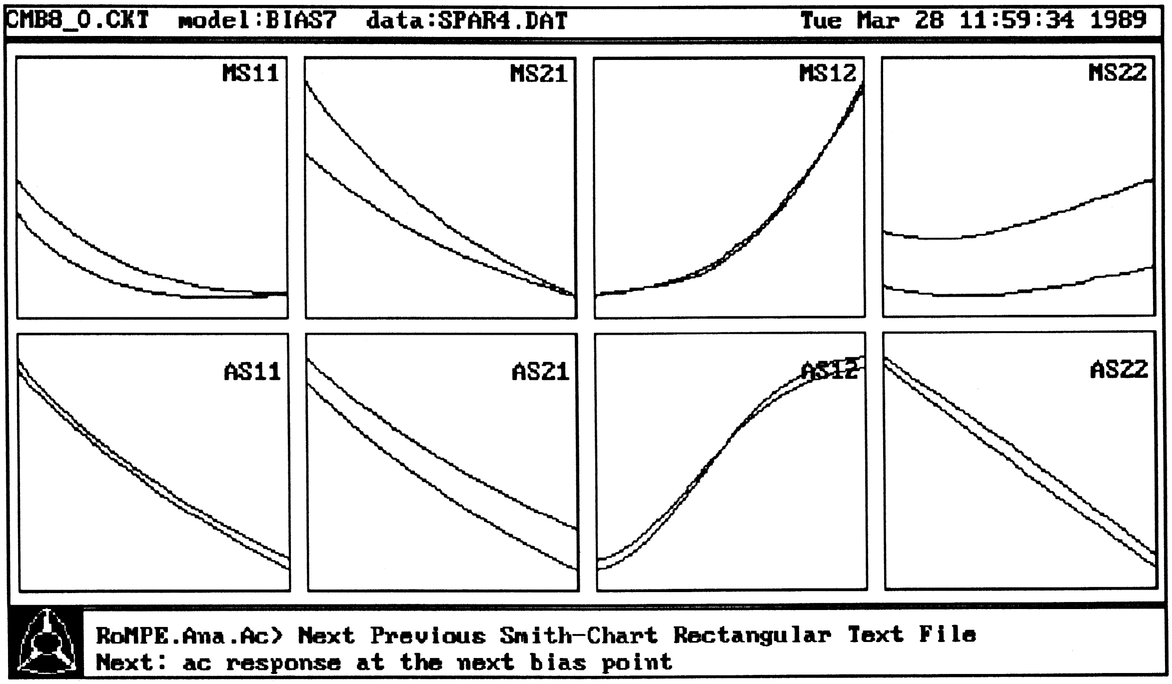


Fig. 7.7 S-parameter match for CMB8_O.CKT.

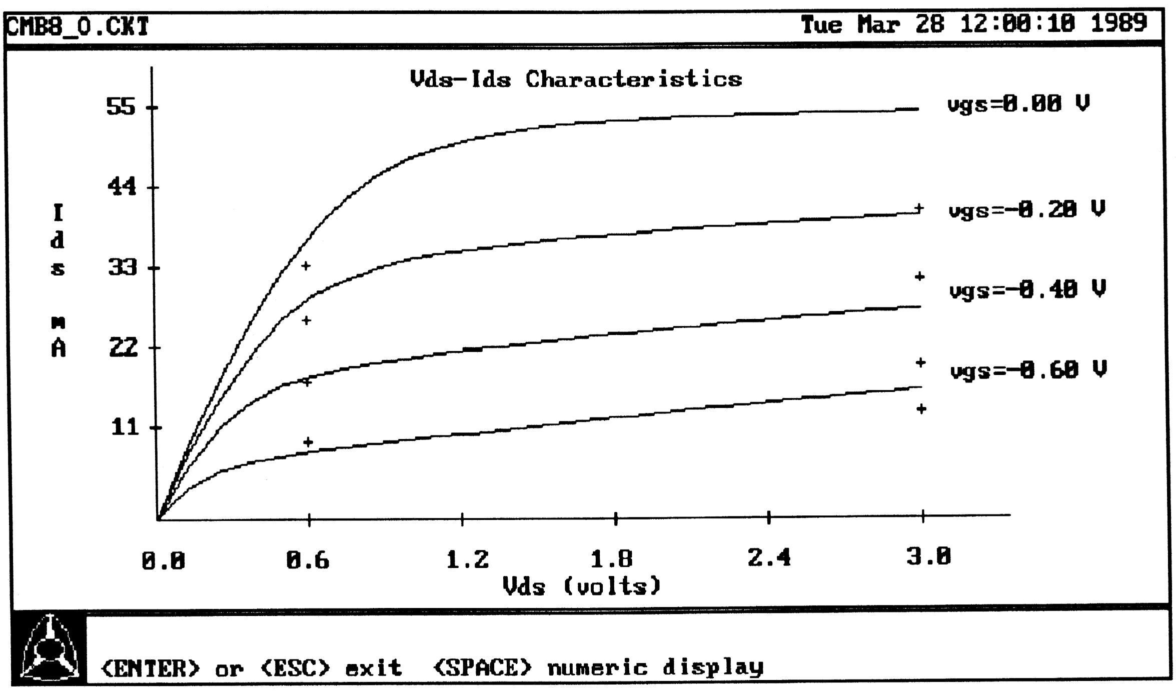


Fig. 7.8 DC match for CMB8_O.CKT.

To further improve the DC match, we can adjust the weights for optimization. Specifically, we reduce the weights on S-parameters relative to the weights on DC data, to place more emphasis on the DC match. The model was re-optimized with the adjusted weights (in file CMB8W.CKT), the result is saved in CMB8W_O.CKT and the match shown in Figures 7.9 and 7.10.

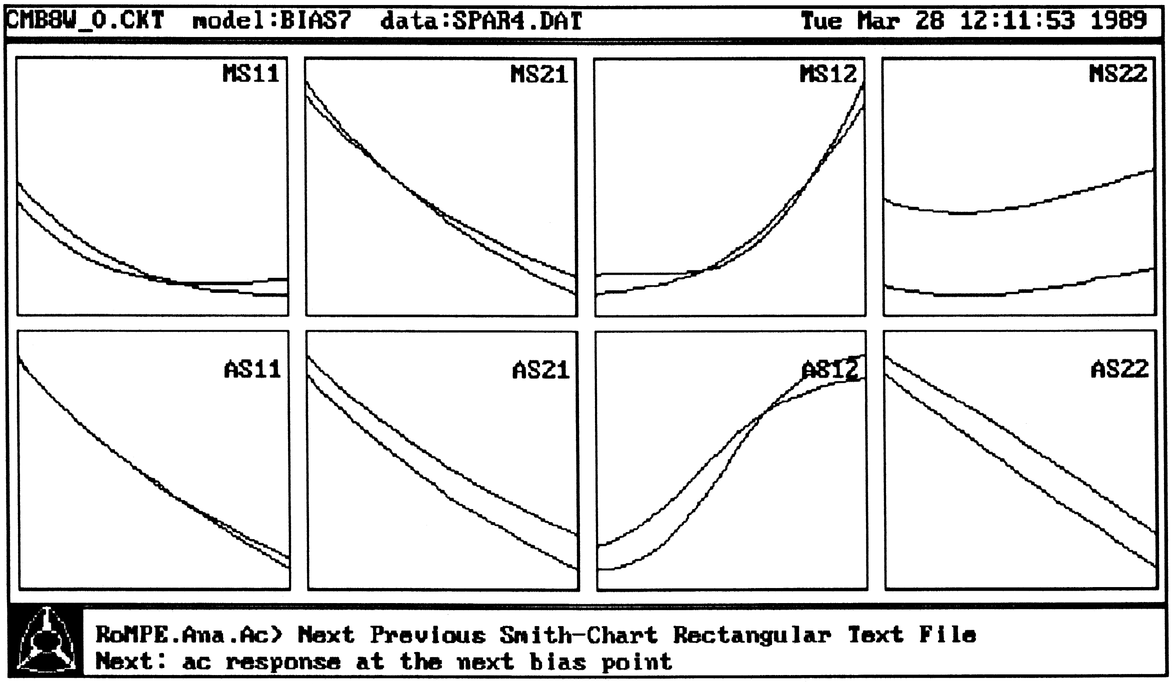


Fig. 7.9 S-parameter match for CMB8W_O.CKT.

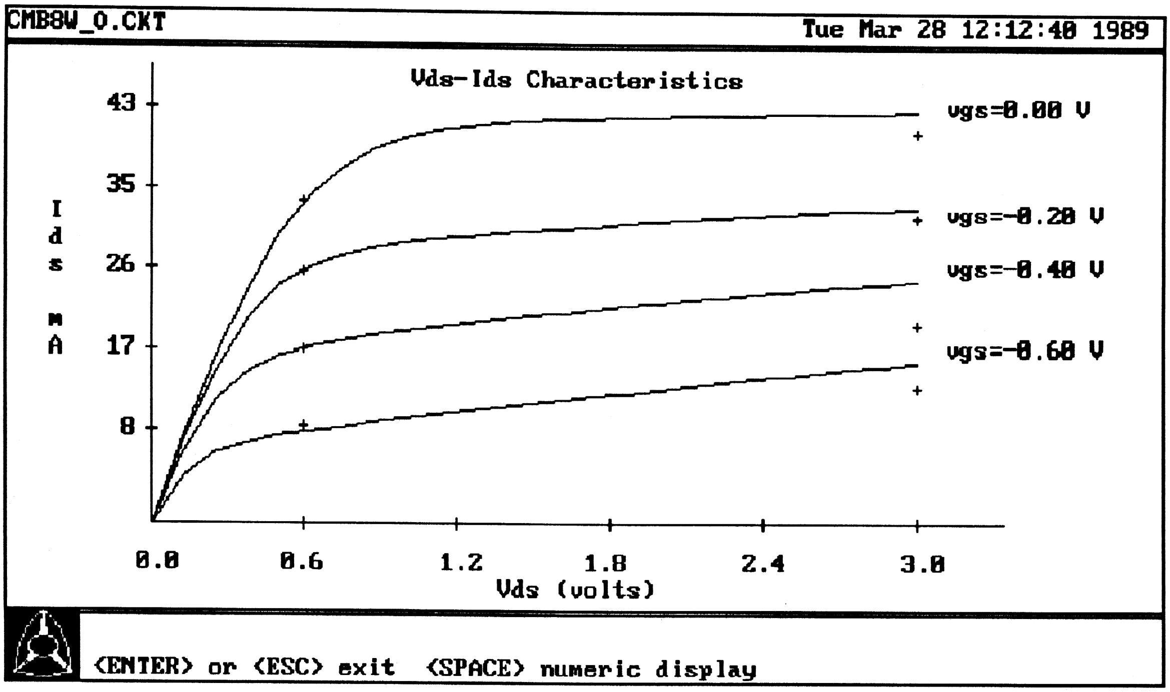


Fig. 7.10 DC match for CMB8W_O.CKT.

We have also performed simultaneous small-signal and DC parameter extraction using 12 bias points. The result in saved in file CMB12W_O.CKT and displayed in Figures 7.11 and 7.12.

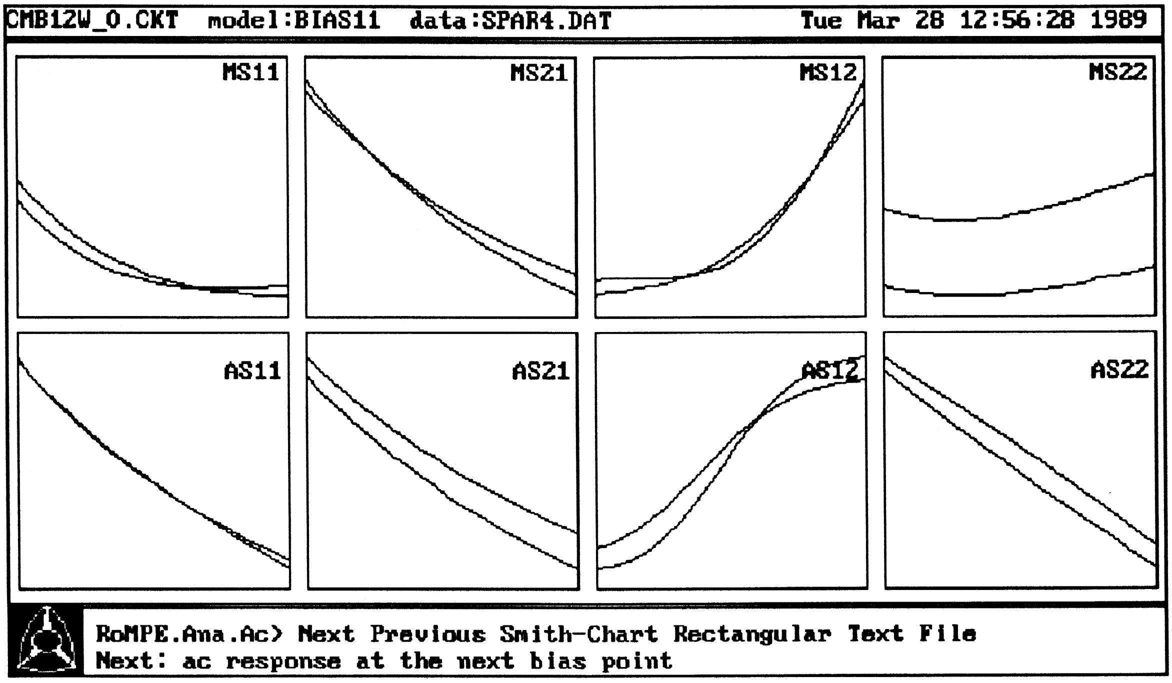


Fig. 7.11 S-parameter match for CMB12W_O.CKT.

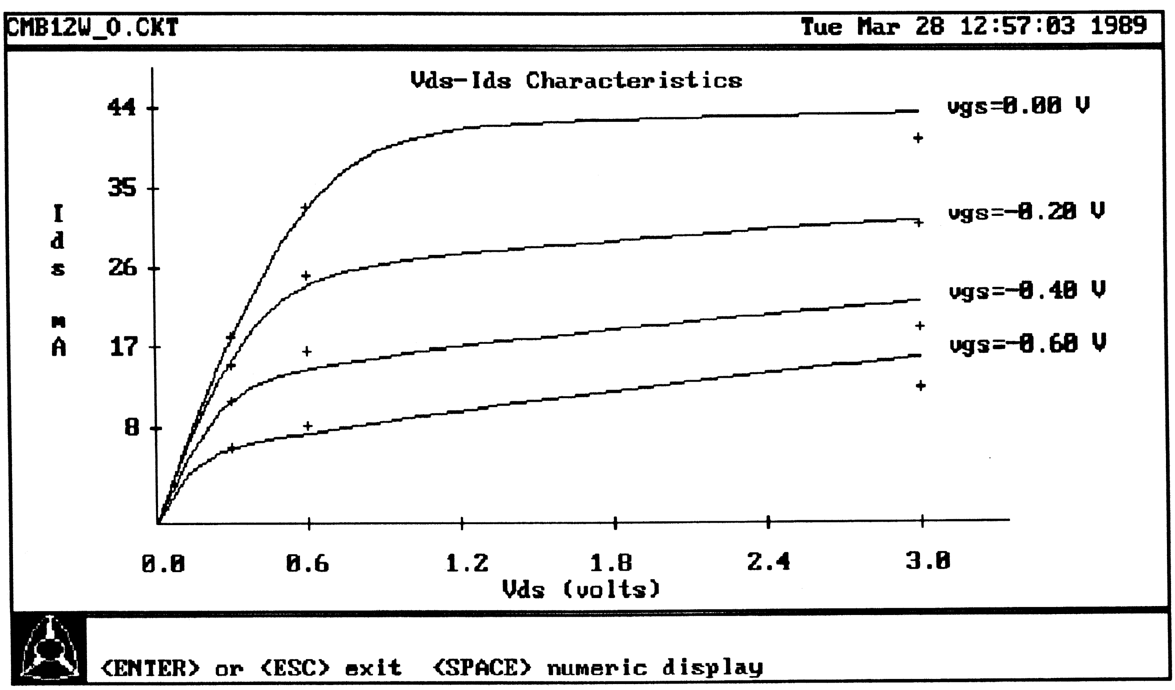


Fig. 7.12 DC match for CMB12W_O.CKT.