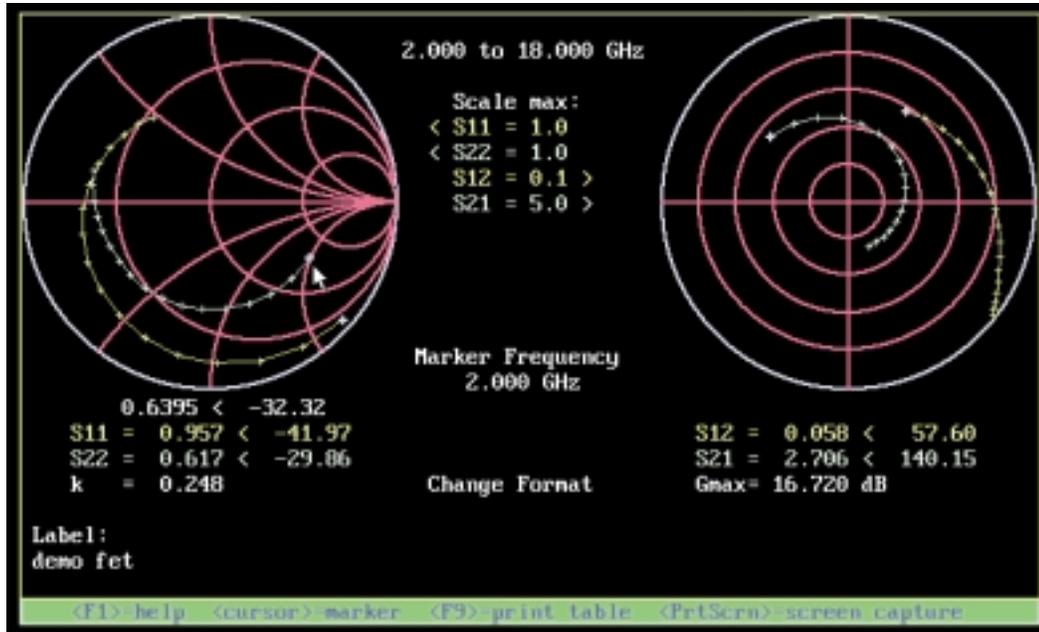


FIXTURE CHARACTERIZATION AND S-PARAMETER MEASUREMENT USING MAURY'S MT956D SOFTWARE



Introduction

Improved and expanded S-parameter measurements using most popular vector network analyzers is now possible with the simple addition of Maury Microwave's S-parameter software model MT956D.

Test fixture characterization is easy and simple, and calibrations can be deembedded to the device reference plane. This is particularly useful when using an automated tuner system or any other device characterization method.

Adapter removal measurement techniques can be applied to most network analyzers. Swept bias S-parameter measurements can be made using automated bias supplies. Fixture and adapter S-parameter data files can be stored on disk for future use.

While some of these features are found in some network analyzer models, they can now be applied to most popular network analyzers currently being used. In addition, in most cases, these features are simpler and easier to use than the built-in capabilities of the newer network analyzers.

Fixture Characterization

To properly make device characterization measurements or measure the S-parameters of a device in a test fixture, the fixture must be properly characterized. That is, the S-parameters of the input and output halves of the test fixture need to be known. The network analyzer calibration then needs to be deembedded to the device reference plane using the S-parameter files.

The MT956D software provides a simple means to both characterize the fixture and deembed the calibration using any of the more popular Hewlett Packard or Anritsu/Wiltron vector network analyzers. The fixture S-parameters can be stored in a file and used at any time. This means that only a coaxial calibration at the network analyzer test port needs to be performed and the software will deembed the calibration to the device reference plane using the previously stored fixture S-parameter file.

The MT956D has three methods for fixture characterization: the 1-port calibration method, 2-port calibration method, and the approximation method.

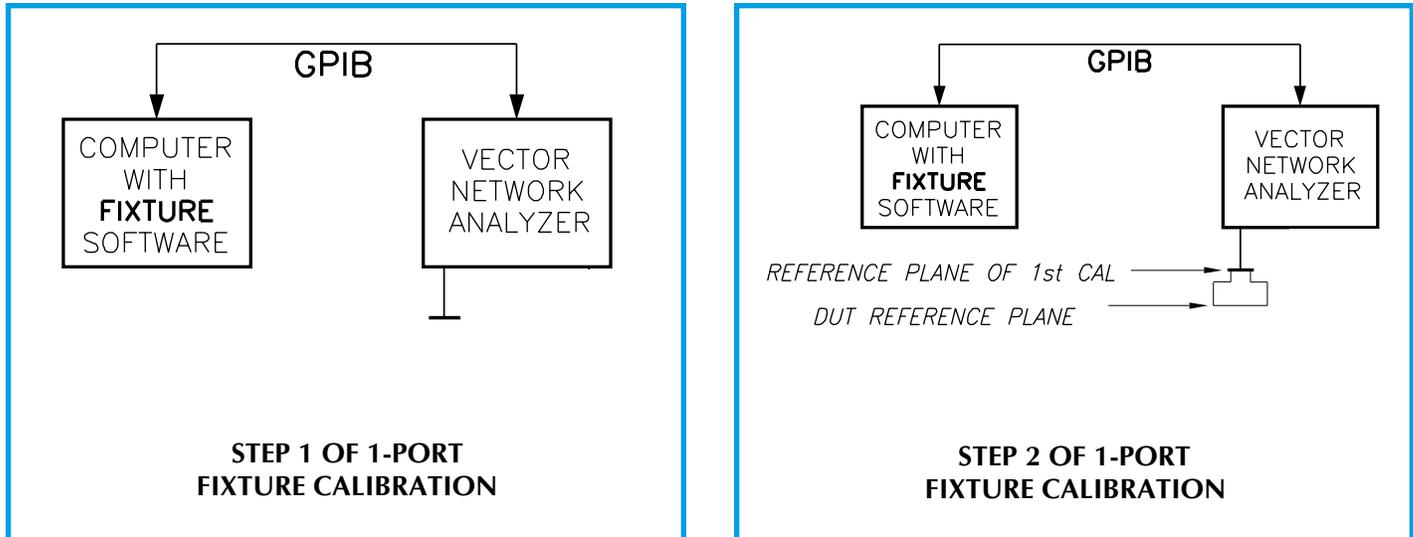


Figure 1

The 1-port method requires two separate 1-port calibrations and is shown in Figure 1. The network analyzer is first calibrated at the reference plane of the analyzer, then the fixture half is inserted and a calibration is done at the device plane using fixture standards. In addition, the electrical length of the fixture is entered (to the nearest $1/4\lambda$) or calculated by the software if the phase change between frequency calibration points is small relative to the fixture length. The software then calculates the S-parameters for the measured half of the fixture and stores them in a fixture file.

The 2-port method shown in Figure 2 requires two separate 2-port calibrations. A 2-port calibration is done at the network analyzer reference plane, then a 2-port calibration is done at the device plane. The 2-port method will work with SOLT, LRM, and TRL calibration methods. The 2-port method can be more convenient because TRL standards are more easily obtained for most fixtures and both S-parameter files are created at the same time.

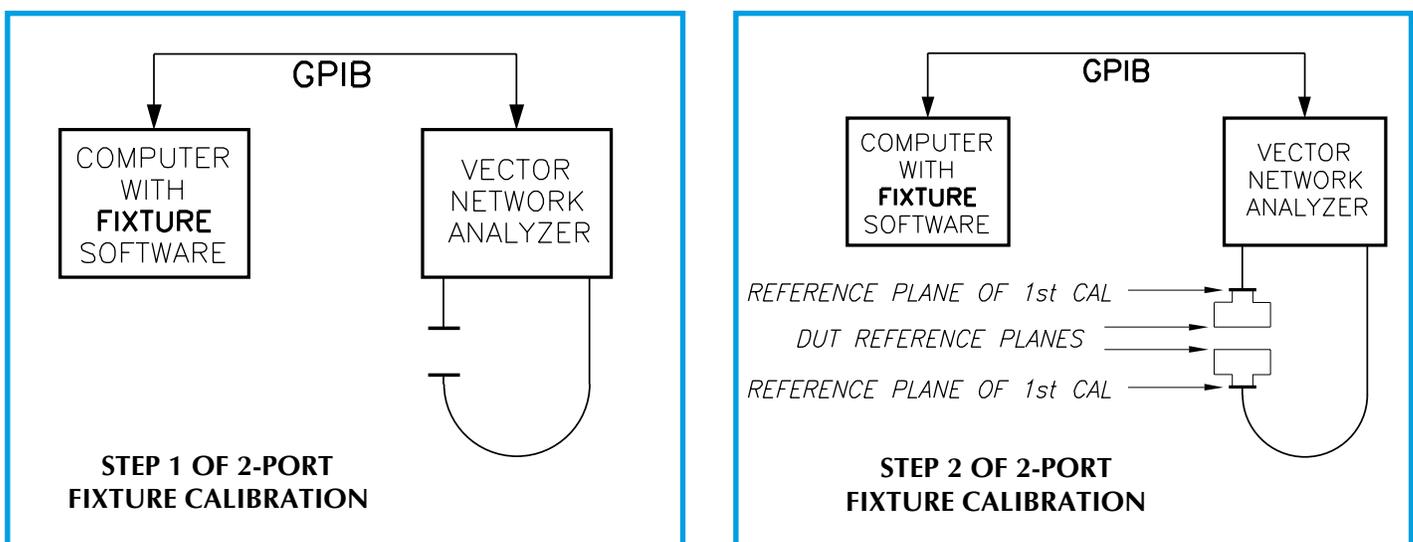


Figure 2



In both the 1-port calibration method and the 2-port calibration method the math required to extract the S-parameters of the fixture halves assumes the fixture is passive and reciprocal. The product of S_{21} and S_{12} is found first and the square root is taken to get the individual parameters. Consideration must be given to the fact that two solutions are possible, equal in magnitude and opposite in phase. This is why the approximate electrical length is needed during calibration. This length can be determined automatically by the software as long as the frequency spacing is small. The problem caused by large phase changes between frequency calibration points is illustrated in Figure 3.

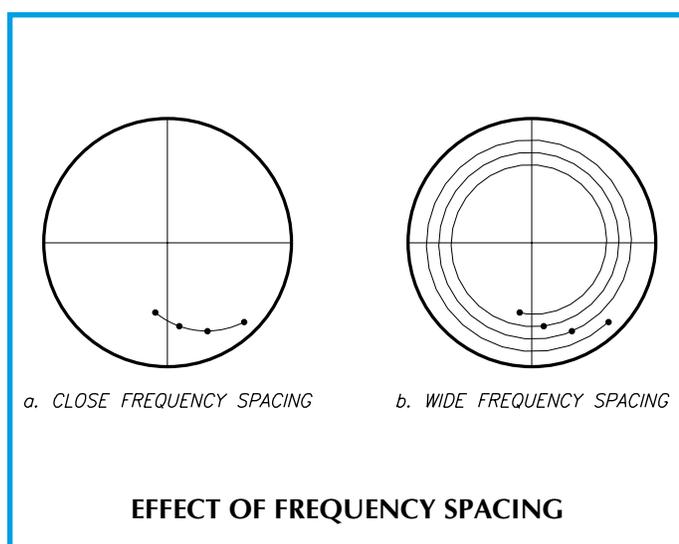


Figure 3

The final method for determining the fixture S-parameters is used if a full calibration inside the fixture is not possible. It is often a good approximation at frequencies below 2 GHz. This method is

based on the assumption that the fixture is reflectionless. S-parameters are calculated from the delay and loss of each fixture half. The delay and loss of the fixture halves is determined by making either a reflection measurement using a complete reflection at the device plane, or by inserting a thru in the fixture at the device plane and making a transmission measurement. Ideally, the thru should be zero length so that it does not contribute any delay to the measurement. If a zero length thru is not used, the delay will have to be determined from the physical length.

The advantage of the reflection method is that both fixture halves are done independently, however, it is more sensitive to mismatch errors. The transmission method is less sensitive to mismatch errors but assumes the fixture halves are symmetrical. Accurately determining the electrical length of the thru is also difficult.

Adapter Removal

One of the classic problems encountered when making reflection or transmission measurements of microwave and RF devices using network analyzers is commonly referred to as measuring a "non-insertable device". The device is considered non-insertable because the test ports cannot be mated to form a zero length, zero loss thru. Unfortunately, many devices measured fall into this category. The MT956D S-parameter software provides a method to accomplish this, which is similar but easier to use than the method used in the HP8510B/C. However, the MT956D software will work with any HP or Anritsu/Wiltron vector network analyzers. The basic approach, shown in figure 4, is to do a 2-port calibration

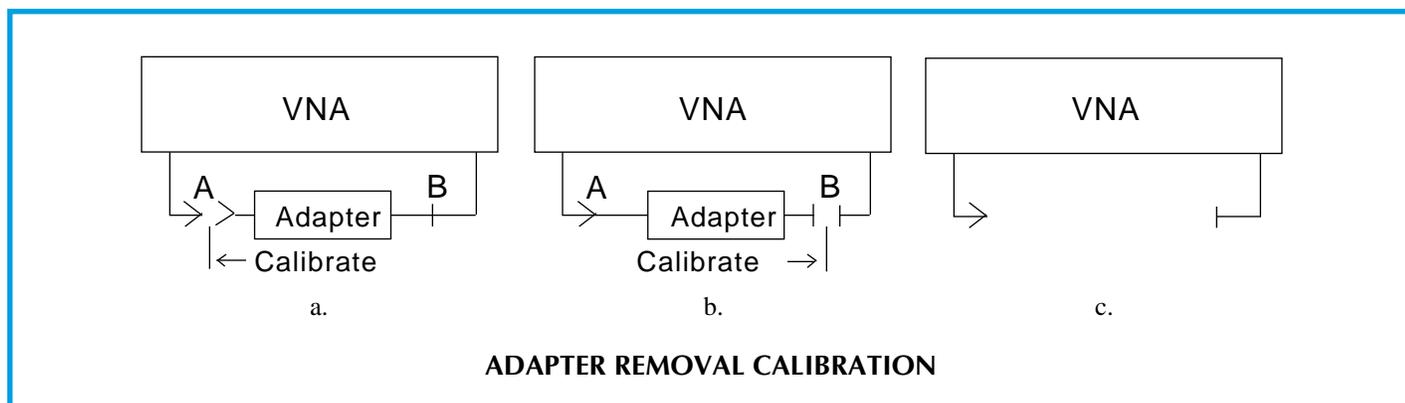


Figure 4



tion on each side of the adapter and then combine them to create a new calibration, effectively removing the adapter from the measurement. The electrical length (to the nearest $1/4\lambda$) of the adapter needs to be entered or calculated in the same manner as the fixture characterization and the phase change needs to be considered the same as with fixture characterization.

A typical use of the adapter removal feature is measuring the insertion loss of a waveguide to coaxial adapter. A waveguide calibration is performed at the waveguide test ports and then a coaxial calibration is performed at the coaxial test ports. For the waveguide calibration, Z_0 needs to be set to 1. The two calibrations are combined and the waveguide to coaxial adapter can be inserted and measured.

Fixed and Swept Bias S-parameter Measurements

The S-parameter features include the capability of making fixed bias or swept bias S-parameter measurements using automated bias supplies and network analyzers. This is an important feature that allows the operator to determine and easily record how a device will operate over a range of bias

conditions at each frequency. A frequency range and bias range are selected and the S-parameters are then measured over those ranges. The data can then be displayed or stored on disk for future evaluation. The software comes with a variety of software drivers for bias instruments and network analyzers.

Cascade and Uncascade S-parameter Files

Displayed S-parameter data can be cascaded or uncascaded with a saved S-parameter data file. A data file is selected and the combined S-parameter data of the selected file and the displayed file are then combined and redisplayed. This is a particularly useful feature in laboratory or production environments where a single calibration is performed on the network analyzer and then cascaded with an S-parameter file previously measured to provide a new calibration reference plane. A typical application would be if several cables with different connector types are being tested. A calibration can be performed with one connector type and previously saved S-parameter files for the required adapters can be recalled and cascaded with the original calibration. This eliminates the need to recalibrate the network analyzer for each change in connector type.

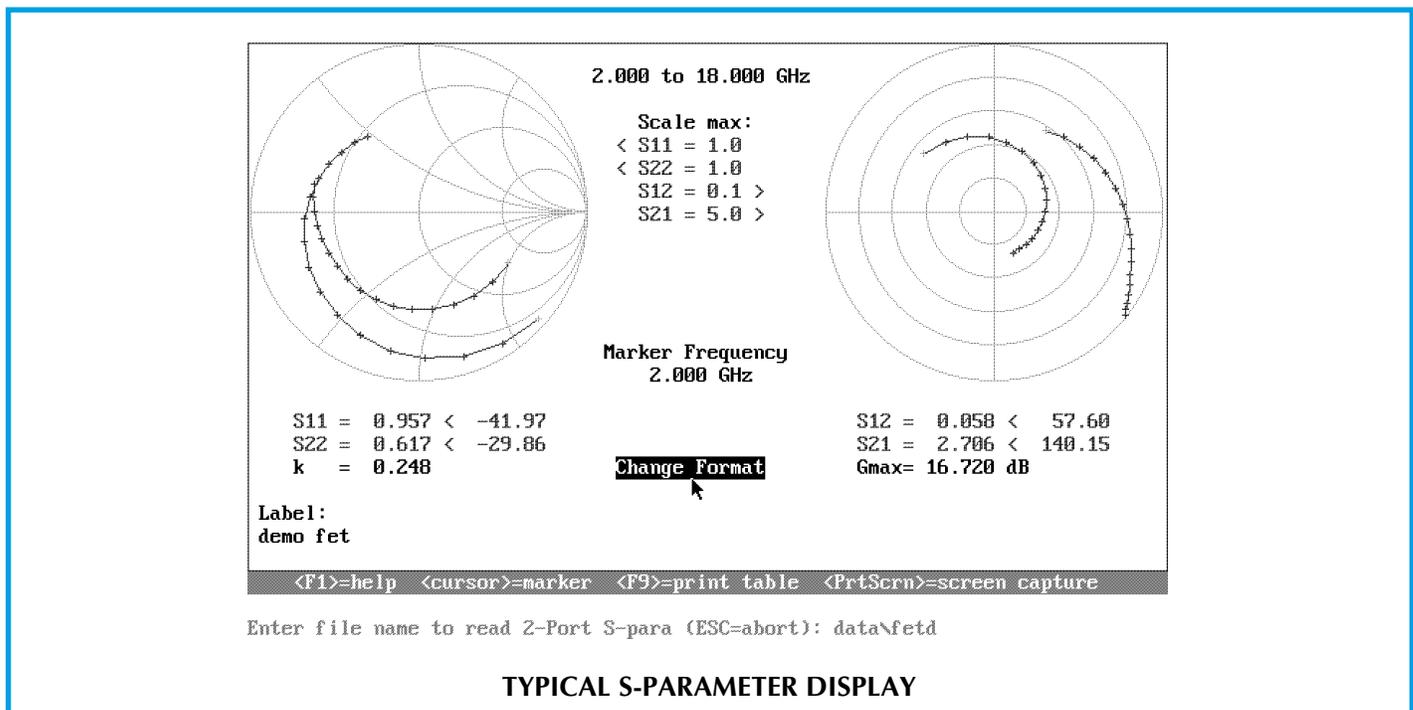


Figure 5

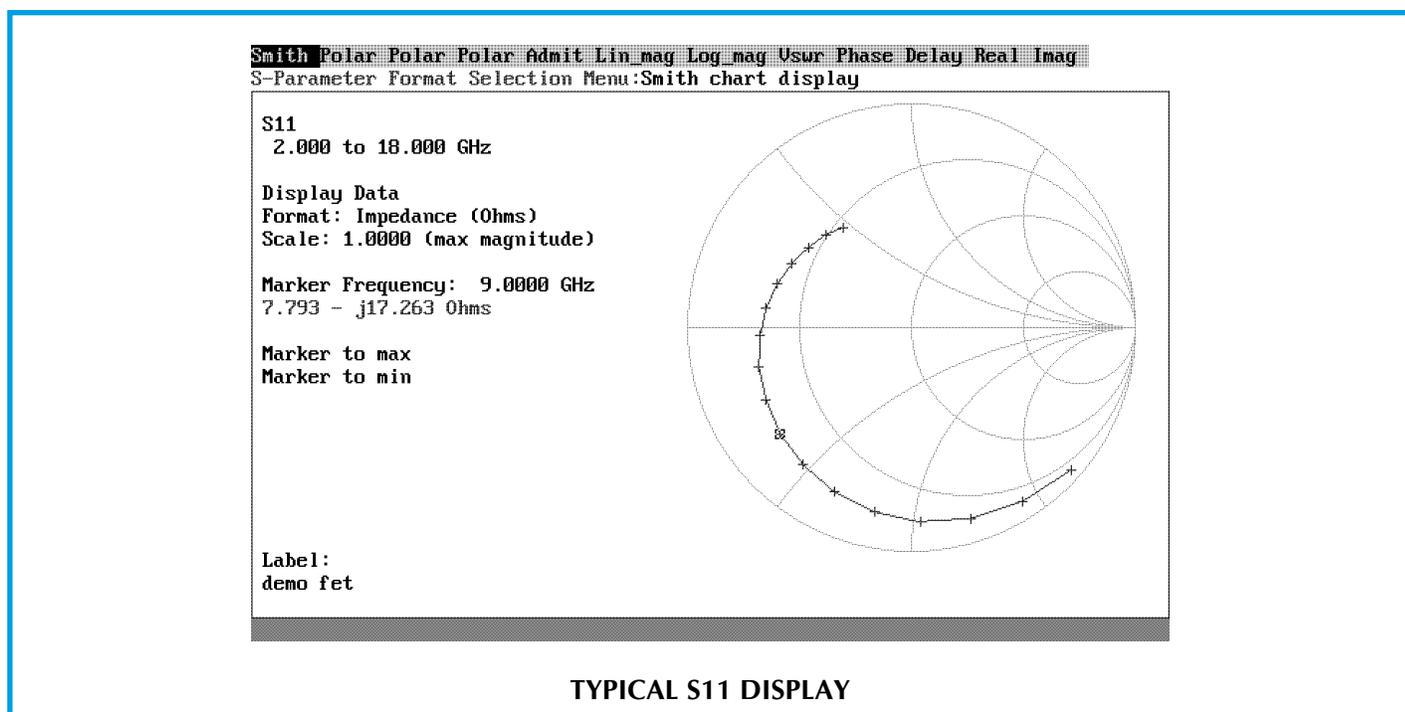


Figure 6

Change Default Impedance Values

The normalized real impedance default value can be changed to a new value. The S11/S21 and S22/S12 normalized default values can be changed independently to a value that allows a more convenient and easy-to-view display. This allows the operator to display their S-parameter measurements at any desired impedance, a very useful feature if devices with very low impedance are being measured or if a fixture with a quarter wavelength transformer is used.

S-parameter Displays

After a measurement is made or a file is recalled, the data is displayed. Any individual S-parameter S11, S21, S22, and S12 can be displayed individually or all four parameters can be displayed simultaneously as illustrated in Figure 5.

The S11 and S22 parameters can be displayed in one of the following formats; Smith chart, polar logarithmic magnitude and phase, polar real and imaginary, linear magnitude, log magnitude,

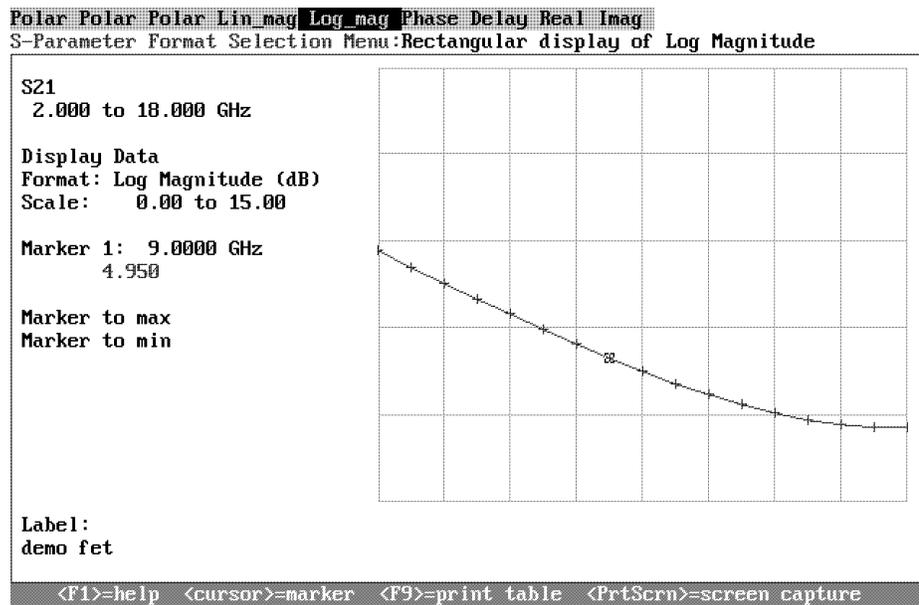
admittance chart, VSWR, delay, phase, real impedance part, and imaginary impedance part as shown in Figure 6.

The S21, S12 parameters can be displayed in polar linear magnitude and phase, polar logarithmic magnitude and phase, polar real and imaginary, linear magnitude, logarithmic magnitude, delay, phase, real impedance part and imaginary impedance part. An S21 log magnitude format is shown in Figure 7.

Summary

As described and illustrated, the capabilities of S-parameter measurements using vector network analyzers can be expanded and simplified by the addition of the MT956D software package and an inexpensive personal computer.

Users needing to characterize their test fixture and make deembedded measurements can do so with much less difficulty. Non-insertable device measurements can be made. Swept bias measurements can be made, and S-parameter files can be cascaded with ease and simplicity.



TYPICAL S21 DISPLAY

Figure 7