Agilent
Combining Network and Spectrum Analysis and IBASIC to Improve Device Characterization and Test Time

Application Note 1288-1

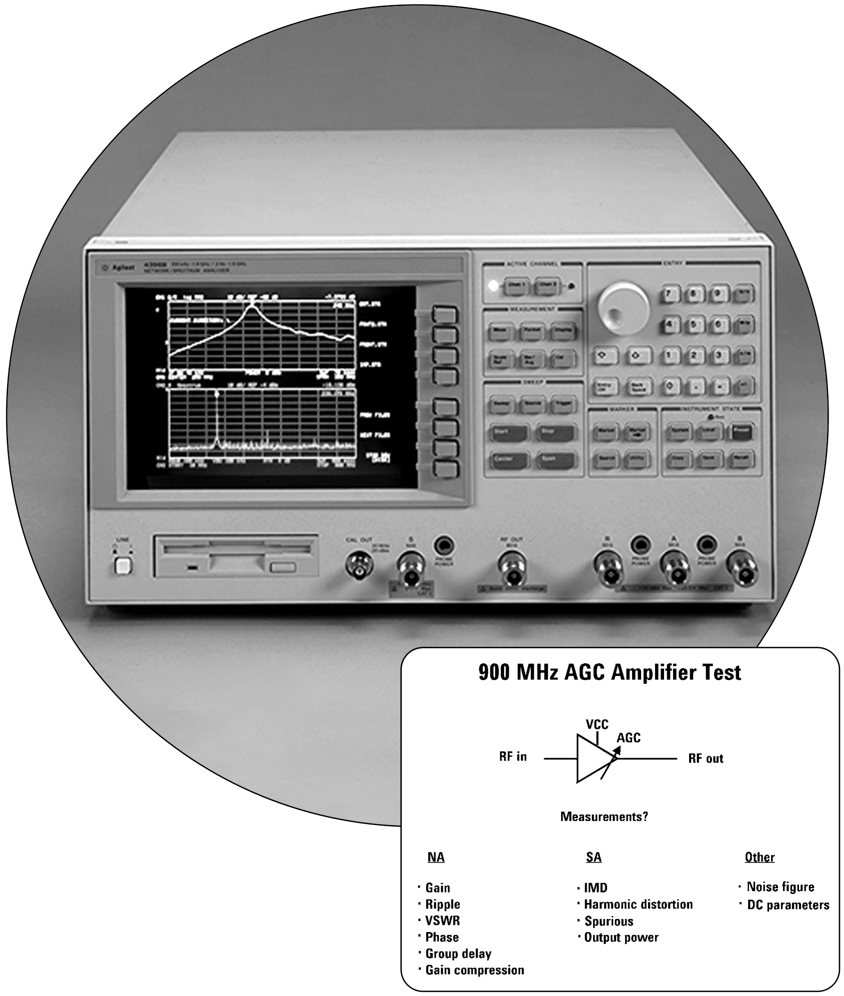
Using the 4396B to analyze linear and non-linear components - a 900 MHz AGC amplifier example

Background

Active components require linear and non-linear analysis

Active components (and now even some passive components like crystal filters) require analysis to characterize linear parameters (gain/loss, phase and group delay or S-parameters) as well as non-linear performance. Non-linear analysis is typically related to measuring signal distortion generated in the device such as harmonic or inter-modulation distortion. Therefore, for complete characterization, both a vector network (VNA) and spectrum analyzer (SA) are required, for linear and non-linear evaluation respectively.

For example, to characterize an amplifier for cellular applications, we are typically interested in the following measurements. Note that 10 out of 12 measurements are made with either a vector network analyzer (VNA) or spectrum analyzer (SA).



Combining vector network analysis, spectrum analysis, and a built-in controller in one instrument offers new capabilities for RF testing.

Introduction

Today's RF designs are increasingly driven by time-to-market. At the same time, advances in digital communication techniques are placing higher performance requirements on components and subsystems. These key driving forces require that comprehensive as well as time and cost effective measurement techniques are used in design and manufacturing. In this note, test approaches using the combination of vector network, spectrum analysis and IBASIC program control are discussed showing ways to get better device characterization with faster results, higher accuracy and increased test flexibility. Additional benefits include improved quality control data and ease of product transfer from design to manufacturing.

Characterization is important but difficult

Accurate characterization if fundamental to both the designer and user of high-performance RF components. Errors in operating parameter measurements or operating in untested regions put the end product at risk. Careful and complete characterization pats benefits during the entire product development cycle by allowing better decisions in design and optimum testing during the manufacturing phase, a large potential cost savings. But to fully characterize RF components often requires numerous test instruments and a large investment of time and effort. Automating testing to gather statistical information involves external computers and programming. In the past, this amount of work has been a real obstacle to comprehensive characterization. If operating data is needed for different or changing conditions, re-configuring the test station required a large commitment of resources and long time delays before the data is available.

Combining instrument functions for improved testing

By combining vector-network and spectrum analyses in the 4396B, and by using the built-in IBASIC programming capability, a powerful new test tool is now available for lab or manufacturing applications. As the core of a mini-ATE system, the 4396B can control and test multiple parameters with a single insertion of the device-under-test (DUT). In addition, tests are easily changed or customized for special operating conditions or one-of-a-kind test requirements. The remainder of this note will use an amplifier test example to illustrate the principles and effectiveness of this approach.

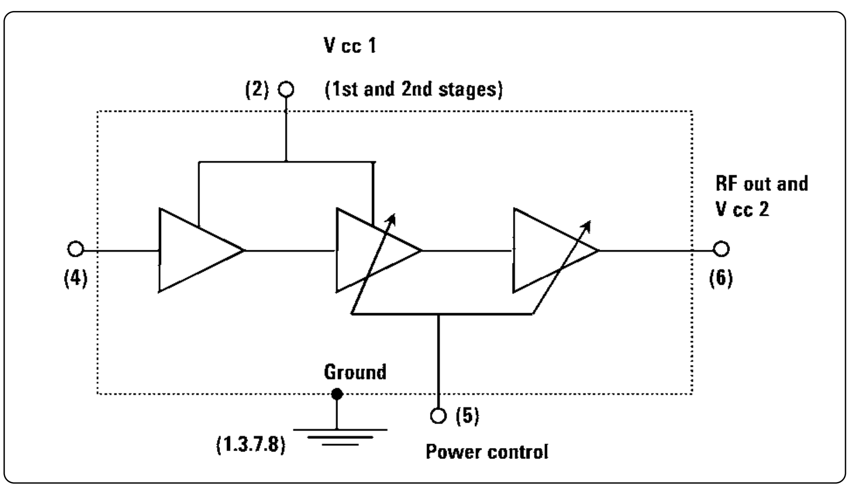


Figure 1. 900 MHz AGC amplifier block diagram

Testing a silicon bipolar MMIC 900 MHz AGC amplifier for cellular applications

In this example, a 900 MHz automatic gain control (AGC) amplifier was characterized using a 4396B-controlled mini-ATE system.

The amplifier's block diagram is shown in figure 1. A test board was used (figure 2) for easy connection using SMA 50 Ω cables. The test system consisted of an 4396B network/spectrum analyzer, two programmable power supply voltage levels, two programmable signal generators for inter-modulation distortion (IMD) measurements and switch-controller with two RF switches. See figure 3.

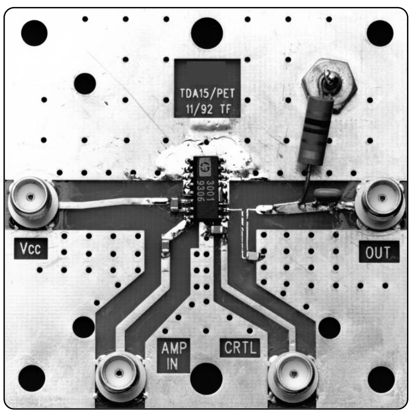


Figure 2. Test board used for automated testing

Fast automated test results

The measurement parameters and results from the AGC amplifier test are shown below. The total time to make these measurements using the test system described was 9.2 seconds. These results are in summary form for easy review and comparison with other devices. A printout was formulated using IBASIC programming as a simple addition to the automatic test control program. (Printing out cursor values from the various network and special data.)

To gain more insight into the measurement techniques used, these specific amplifier test are discussed in more detail:

- Inter-modulation distortion (IMD)
- Gain vs. AGC control voltage
- Performance change with different power supply voltages

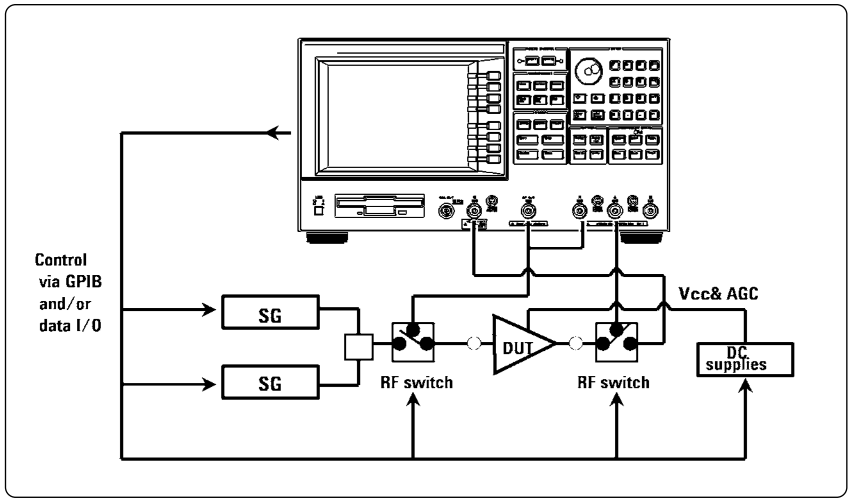


Figure 3. Automated test system for component characterization.

Amplifier Measurement Results
(total measurement time = 9.2 seconds)

Parameter	Symbol	Value
Output power	Pout	23.9 dBm
1 dB gain compression	P1 dB	23.1 dBm
Power control range	Pcr	69.2 dB
Small signal gain	Gain	34.4 dB
3rd order intercept pt	IP3	30.2 dBm
Input return loss	IRL	-20.3 dBm
Control current	Icont	2.2 mA

Inter-modulation distortion (IMD)

Inter-modulation distortion is a critical measurement because these distortion products can fall in adjacent channels in the cellular radio band. Thus it is important to characterize them accurately and then reduce them in the design of the system. Harmonic distortion is also important, but these products are more easily removed by low- pass filters. See figure 4.

Two signal sources are used for IMD, and SA is then used to measure the third-order, and for this amplifier, fifth-order products. An example IMD measurement is shown in figure 5 using sources separated by 1 MHz for ease of identifying IMD signals. In this case the distortion products are easily distinguished from the noise floor. However, for many measurements, the IMD values may be much lower, and hard to distinguished in the noise floor of the SA. For this case, a narrower resolution bandwidth (RBW) is often used, but this increases the sweep time. In addition, IMD signals may be much closer together than in this example. When IMD signals are separated only by 10 to 50 kHz ,the RBW must be reduced in order to resolve the signals. In conventional spectrum analyzers, narrow RBWs can drastically slow down a measurement. The 4396B uses a 'stepped-FFT' technique for all RBWs of 3 kHz and below. This result in a factor of 10 to 100 times faster sweep time compared to non-FFT assisted spectrum analyzers. Throughput improvements for IMD measurement are a major advantage of using the combination analyzer for narrow resolution, wide dynamic range measurements.

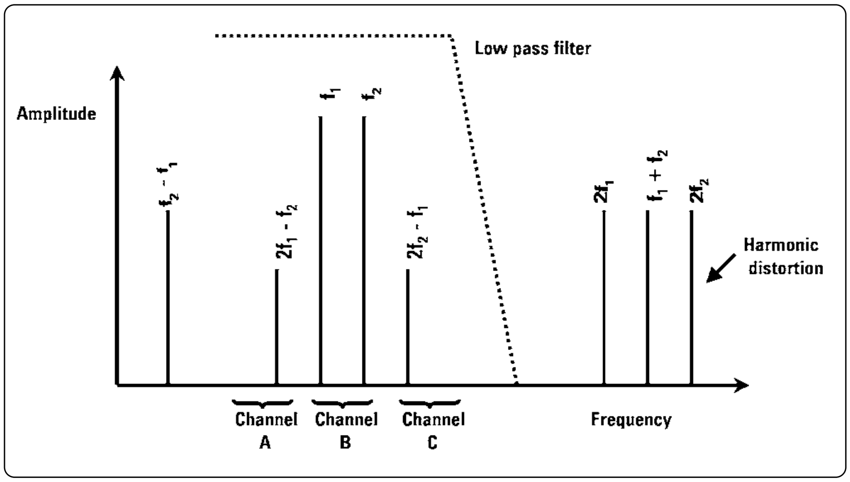


Figure 4. Inter-modulation distortion (IMD) products from channel B signals f1 and f2.

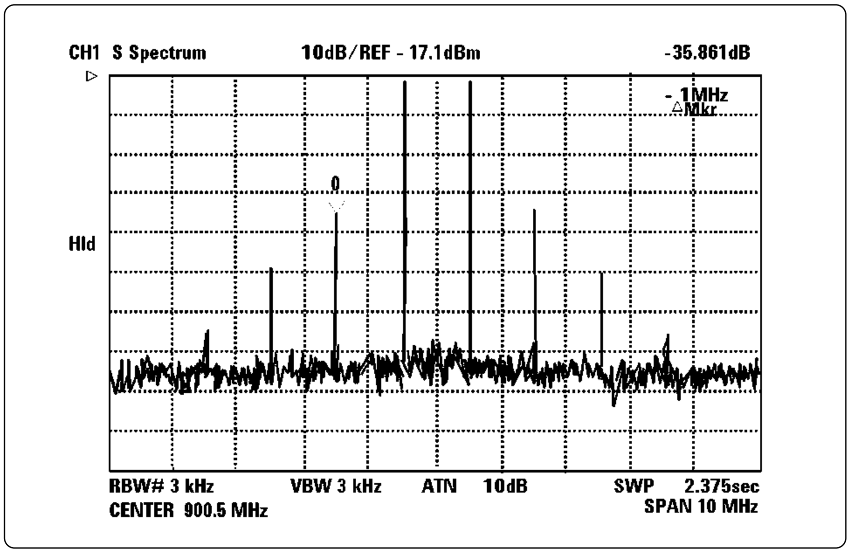


Figure 5. Third, fifth, and seventh order IMD products. Third order shown on cursor.

List sweep technique improves SA measurement speed

With the 4396B, low-level IMD signals can be measured very quickly using a feature called list sweep. List sweep allows the spectrum to be broken up into up to 15 segments. Each segment can have unique start and stop frequencies and different RBW settings. The test engineer can select a segment with narrow RBW (slower sweeps and lower noise floor) targeting only the regions containing the distortion products. The high-level test signals are measured with wide RBW for highest speed, and the frequencies in between can be skipped.

Figure 6 shows almost 7x speed improvement using list sweep in measuring the test system IMD floor. (The unbalance of distortion is due to unbalanced signal] generators). In the right-hand display, note the lower noise floor for the segments where the IMD products are located, resulting from a narrow RBW selection. List sweep speeds harmonic distortion measurements as well, by skipping frequencies between the harmonics.

IMD as a function of signal level

IMD is dependent on signal level. IBASIC can be used to automatically measure IMD products over a range of power levels. In this example (figure 7) the test system IMD noise floor was tested as a function of the dual-source level, and IBASIC displayed mode. Note that the best system noise floor is with signal of -10 to -25 dBm. If made manually, this measurement would be extremely time consuming, considering the 9 signal levels and multiple readings.

Gain vs. AGC control voltage

Figure 8 shows the gain over the 900 MHz band as a function of AGC control voltage. This measurement is easily automated using IBASIC and throughput is increased due to the network analysis speeds as fast as 350 µsec/pt. Instead of manually changing the control voltage and measuring the gain, the dc power supply and make gain measurements.

Figure 9 shows a simplified version of the IBASIC program used on the left. On the right, 4 lines of code are added to also vary the input power. This automatically provides gain vs. control voltage vs. input power enabling the user to determine the optimum and worst-case performance of the amplifier. Getting a ‘three-dimensional’ parameter analysis gives much more information, and the IBASIC programmed measurement control greatly simplifies the task.

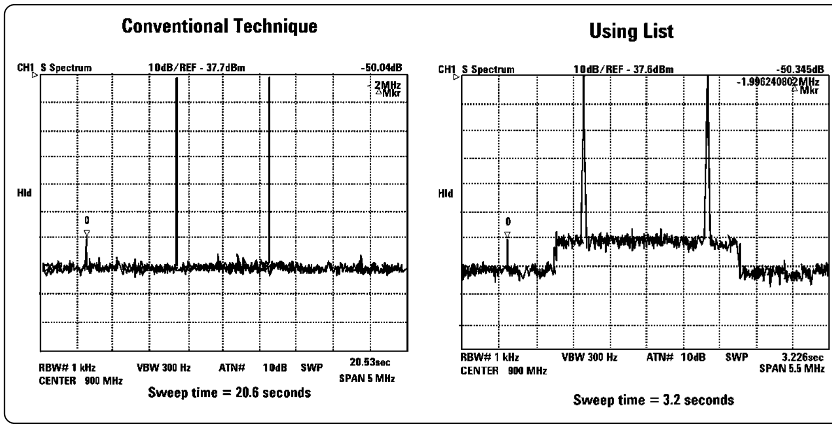
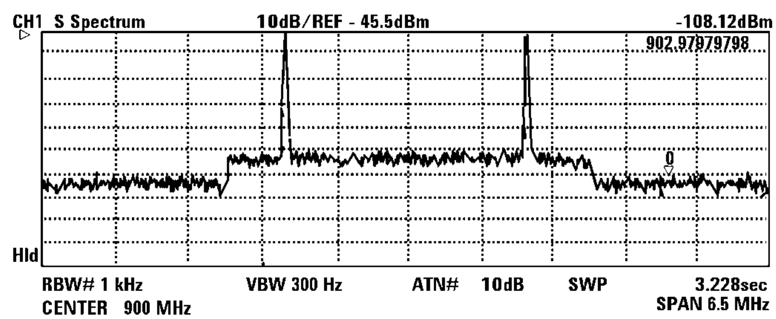


Figure 6. For IMD testing, using list sweep to segment the spectrum to use different RBWs and skipping unneeded frequencies increases throughput.



Sig GenPower	IMD Floor
0 dBm	-50.840741 dBc
-5 dBm	-73.03064 dBc
-10 dBm	-81.91602 dBc
-15 dBm	-81.15534 dBc
-20 dBm	-75.73333 dBc
-25 dBm	-80.2425 dBc
-30 dBm	-72.76329 dBc
-35 dBm	-67.23356 dBc

Figure 7. IBASIC results (lower display) and IMD list sweep spectrum (upper trace) for test system IMD floor test as a function of test signal level.

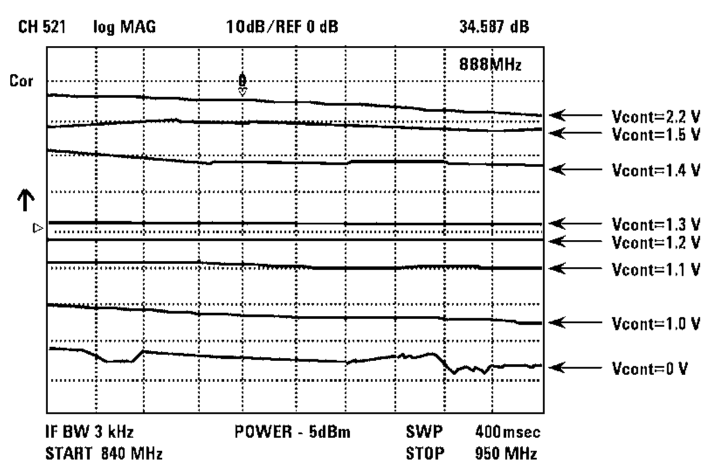


Figure 8. Amplifier gain as a function of AGC voltage.

Performance changes with-different power supply voltages

The typical performance for this amplifier is given for two power supply voltages: Vcc1 = 4.5 V and Vcc2 = 6.0 V. Often designers or users require performance parameters at different conditions. What is the performance at Vcc=Vcc2=5 ? Using this automated system, a minor modification to the characterization program provides quick answers. Figure 10 shows the results as a function of the supply voltage change.

Getting quality control data

When characterizing components, the repeatability of the test system must be quantified. In this system, the use of RF switches may affect the test results. A simple IBASIC program can be used to automatically determine the repeatability and accuracy of measurements made with and without the switches. 100 sweeps were measured to test the effect of the switches. The worst case data spread was 0.049 dB without the switches and 0.050 dB with the switches. In manufacturing, a simple yet powerful method to improve quality is through control charts. By using a program to measure the test station's accuracy and repeatability at regular intervals, any problems can be seen as they develop. The built-in floppy disk can store an auto-start IBASIC program that the operator runs each day to test the system. Results can be used to make control charts and monitor the system performance. This simple procedure can eliminate many component test problems. An example repeatability control chart is shown in figure 11.

Gain vs. Control Voltage	Gain vs. Control Voltage vs. Input Power
⋮	⋮

```
Gain vs. Control Voltage
   ⋮
100 SUB ACC
110 ForVcont= 0 to 2.2 Step 0.1
120 OUTPUT @ DC supply;"1",Vcont
130 GOSUBTake_meas
140 GOSUBstore_meas
150 Vcont
   ⋮

Gain vs. Control Voltage vs. Input Power
   ⋮
100For Pin = -20 to 0 step 2
110 OUTPUT @ Agt4396;"POWE",Pin
120 GOSUB AGC
130 Next Pin
   ⋮
```

Figure 9. Adding a few lines to the IBASIC program varies a third parameter (input power) for 'three-dimensional' parameter analysis'

	V_{cc1} =4.5 V, V_{cc2} =6.0 V	V_{cc1} =5.0 V, V_{cc2} =5.0 V	Difference
Pout =	23.9dBm	23.6dBm	-0.3 dB
P1dB =	23.1dBm	22.4dBm	-0.7 dB
Pcr =	69.2 dB	68.8 dB	-0.4 dB
Gain =	34.4 dB	34.9 dB	+0.5 dB
IP3 =	30.2dBm	29.1dBm	-0.9 dB
IRL =	-20.3 dB	-18.5 dB	-1.8 dB
Icont=	2.2 mA	2.2 mA	——

Figure 10. Performance change with supply voltage change.

Control Chart

Process: Repeatability of network analysis measurements

(IBasic program : NAREPEAT)

Date	1/1	1/7	1/14	1/28	2/4	2/11	2/19
Deviation (dB)	.042	.046	.037	.040	.036	.040	

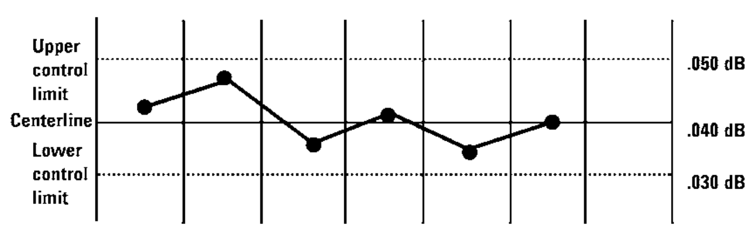


Figure 11. Sample repeatability control chart using an IBASIC test program performed each week.

Transferring products to manufacturing and manufacturing test

Time-to-market pressures mean that efficient transfer of component or subsystem test from design to manufacturing is required. The 4396B analyzer with IBASIC program control simplifies the transfer. Often simple modifications to the original characterization program to test only at critical specifications points is all that is required. Using the same setup in both design and manufacturing saves valuable time during the manufacturing transition and eliminates correlation problems. In addition, the fast measurements speed capability of the 4396B is ideal for high-throughput VNA and SA test requirements. Another critical issue in manufacturing is test flexibility to meet special customer demands. Since the test system is easily programmed (using the keyboard, or by keystroke recording from the front panel), it's easy to respond to special requests quickly. Test documentation is easy too. Direct print function as well as graphic display 'save-to-disk' capabilities for import to PC-based word-processing programs provide numerous ways to get quality hard copy of results.

Fast test program development shortens design cycles

Engineer productivity is increased as the time to fully characterize components and program an automated test station is drastically reduced. The test program used to obtain the 9.2 second overall amplifier test shown was developed in about 34 hours. And it was easily modified to test additional parameters. This task could take one to two weeks using conventional approaches and an external controller.

Conclusion

This amplifier test example and the related discussion illustrates how the Agilent 4396B combination analyzer improves device characterization and reduces test time. High performance features like list sweep, low noise floor, fast sweep speeds, and high accuracy mean that results are not compromised. Additional modification and quality monitoring as well as simplified transfer to manufacturing. These benefits apply also to amplifier testing, but also to any device or subsystem that requires both network and spectrum measurements. In fact, the power of a built-in controller with IBASIC and the high speed of the analyzer make it ideal for any NA or SA automated testing application.

Applying the Agilent 4396B network/spectrum analyzer to your application

Application support, IBASIC programming consulting or program generation, as well as general measurement assistance is available from Agilent Technologies Application Support Staff. Contact your local Agilent Technologies sales office for more information about the wide range of training, service and support products available.

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Printed in USA , August 30, 2001
5965-7656E

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