Agilent
Improving Scalar Network Analysis Using the PSG Signal Generator and the 8757D Scalar Network Analyzer

Application Note 1435

Introduction

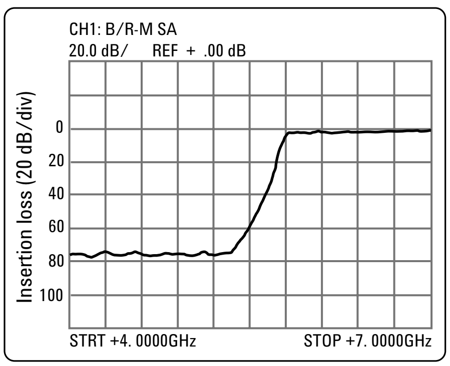

Figure 1a. Approximately 75 dB dynamic range measurement of a 6 GHz high-pass filter using the Agilent PSG signal generator and Agilent 8757D scalar network analyzer in a conventional setup

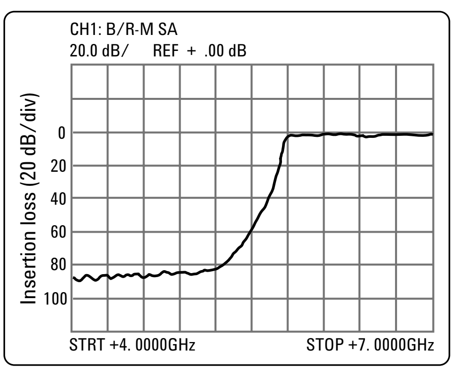

Figure 1b. Greater than 75 dB dynamic range measurement of the same 6 GHz high-pass filter. This measurement was made using the same equipment and setup of Figure 2

Many microwave devices such as filters, attenuators and switches have scalar transmission responses beyond the 75 dB dynamic range of the Agilent 8757D scalar network analyzer. Greater dynamic range (> 91 dB) can be achieved using the Agilent PNA Series network analyzers. Unfortunately, vector network analyzers of this kind are relatively expensive to use. However, by using a high performance microwave signal generator in combination with a scalar network analyzer that measures both swept and CW frequencies, the valuable benefits of economy, convenience, and extended dynamic range can be realized in one measurement system.

This application note describes ways to optimize your scalar network analysis when using Agilent's PSG signal generators (consists of the E8267C (up to 20 GHz) vector signal generator, E8257C analog signal generator (up to 40 GHz), and E8247C CW signal generator (up to 40 GHz) with the Agilent 8757D scalar network analyzer. The PSG is controlled by the 8757D scalar network analyzer via GPIB. This scalar network analysis configuration extends the dynamic range of swept or CW frequency transmission measurements greater than 75 dB. Figures 1a and 1b contrast the results that can be achieved using a conventional setup versus an extended dynamic range configuration. Naturally, the actual dynamic range and measurement accuracy depend on the specific equipment used. The following discussions of setups, operations and results address the general case, enabling the user to create their own configuration from standard Agilent scalar measurement equipment. Specific Agilent examples are also provided for illustrative purposes.

Although this document is oriented towards the Agilent 8757D, the Agilent 8757A/C/E scalar network analyzers can also be used with the PSG signal generators in a manual mode. This manual mode configuration will require RF cables for rear panel connectivity. There is no GPIB connectivity for this test setup. This in turn provides limited parameter annotations on the 8757A/C/E CRT, unlike the capability provided when using the GPIB connectivity with the 8757D scalar network analyzer.

Agilent Technologies

Setup and Operation

In an extended dynamic range setup, the calibrated dynamic range of the reference channel (R) is combined with the calibrated dynamic range of the transmission channel (B) in a ratio (B/R) measurement. This is made possible by externally leveling the source and including the device under test (DUT) within the leveling loop.

When the DUT has no insertion loss, the automatic leveling circuitry of the source will hold the power level seen at the "B" detector constant at a previously calibrated level, say +10 dBm. As the DUT begins to attenuate the power to the "B" detector, the leveling loop will try to compensate by raising the output power of the source. This increase of power level will be monitored in the "R" detector and will decrease the "B/R" ratio display of the scalar analyzer accordingly.

This automatic process will continue, as the DUT attenuation varies, until the maximum output power of the source can no longer compensate for the attenuation of the DUT. At this point, the source output power will remain constant at its maximum level; likewise, the "R" detector power level will remain constant. Then the power level at the "B" detector will begin decreasing with increasing DUT attenuation, causing the "B/R" ratio to decrease according to the DUT's transmission test response. This decrease will continue until the DUT attenuation lowers the power level to the sensitivity of the "B" detector (at least -60 dBm). At this point, the "B/R" ratio will once again remain relatively constant, establishing the dynamic range of the scalar measurement system. A quantitative accounting of this operation is presented in Table 1.

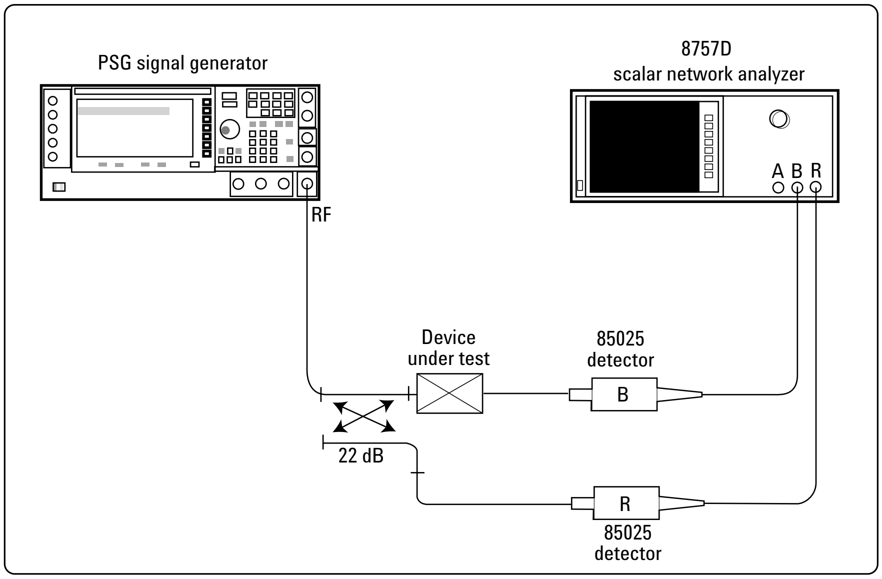

Figure 2. Increased dynamic range using a high-power source

DUT attenuation	Source P_0 (P_B + DUT Att)	B-Det. P_B (P_0 - DUT Att)	R-Det. P_R P_0 - 22 dB
0 dB (Calibr.)	+10 dBm	+10 dBm	–12 dBm
10 dB	+20 dBm	+10 dBm	–2 dBm
20 dB	+20 dBm	0 dBm	–2 dBm
10 dB	+20 dBm	+10 dBm	–2 dBm
40 dB	+20 dBm (P_0 Max.)	+10 dBm	–2 dBm
60 dB	+20 dBm	–40 dBm	–2 dBm
80 dB	+20 dBm	–60 dBm	–2 dBm

Table 1. Power levels versus DUT attenuations

Using a High Power Source to Extend Dynamic Range

Conventionally, when extending the dynamic range of scalar analysis measurements, the configuration would require a microwave source, external amplifier (to increase the output power of the source), and scalar network analyzer. Today, when using the PSG signal generator to extend the dynamic range of a scalar measurement, an external amplifier is not required. This reduces costs and lowers the distortion level that the external amplifier would add to your configuration. Now, the scalar analysis can be realized by using a high power microwave signal generator (in Figure 2, an Agilent PSG signal generator is used in the configuration as the effective source). The dynamic range of this setup is primarily dependent upon the maximum unleveled output power of the effective source. The effective source can consist of a high-power microwave CW, analog, or vector signal generator with ramp sweep capability.

The minimum achievable dynamic range is calculated as shown below.

Po - Sa = **Minimum achievable dynamic range**

Po = **Maximum unleveled output power of the effective source (+ 25 dBm, typically, for the Agilent PSG CW or analog signal generator).**

Sa = **Sensitivity of the Agilent 8757D scalar network analyzer (at least -60 dBm).**

Thus, the dynamic range of the example shown in Figure 2 is:

Minimum achievable dynamic range = + 25 dBm (typically) - (-60 dBm) = 85 dB

Keep in mind this calculation depends upon the items discussed in a later section, "Limiting Factors of Dynamic Range."

In general, the setup in Figure 2 provides a way to translate any source output power above +10 dBm directly into increased dynamic range of the scalar measurement system.

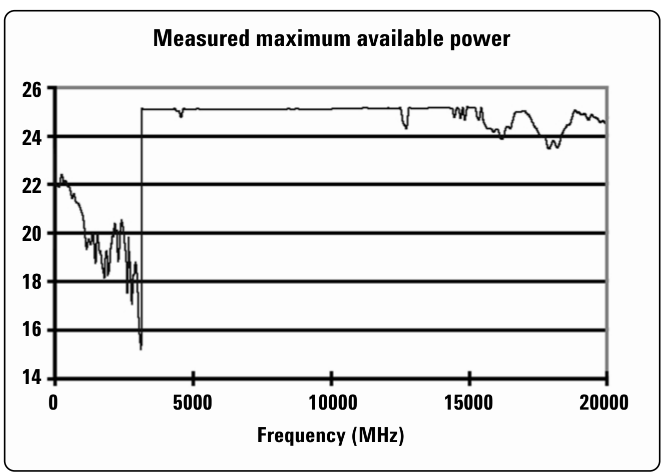

Figure 3a. E8247/57/67C PSG signal generators – 20 GHz models with Option 1EA

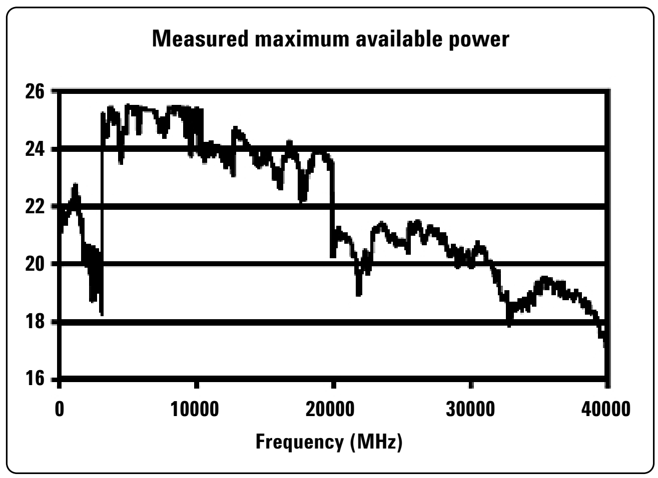

Figure 3b. E8247/57C CW and analog signal generators – 40 GHz models with Option 1EA

Limiting Factors of Dynamic Range

Other factors that determine dynamic range, in addition to those already discussed, are described below.

Leveling modulator control range

The minimum dynamic range is dependent on the range of values that the source outputs. The leveling modulator of the source's automatic leveling circuitry (ALC) must be capable of varying the output power over a range greater than the amount the dynamic range is expanded. A close look at the leveling system indicates why. As the DUT attenuation varies, the leveling circuitry of the source tries to compensate. As a result, the RF leveling modulator varies the output power of the source over a wide range. Since this is not a normal application of the leveling circuitry, the source data sheet cannot be expected to provide complete information about the modulator control range.

Harmonics and spurious signals

Source harmonics and other spurious signals can reduce the dynamic range of a scalar transmission measurement since the 8757D scalar network analyzer uses a broadband detection scheme. The PSG signal generators have very low harmonics (< -50 dBc). Figure 4 displays the harmonics generated at the respective frequency ranges for the PSG signal generators:

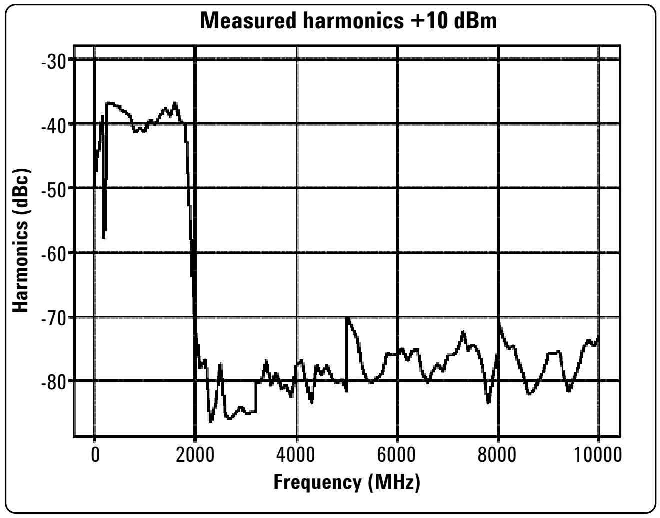

Figure 4a. 20 GHz measured harmonics for E8267C PSG vector signal generator

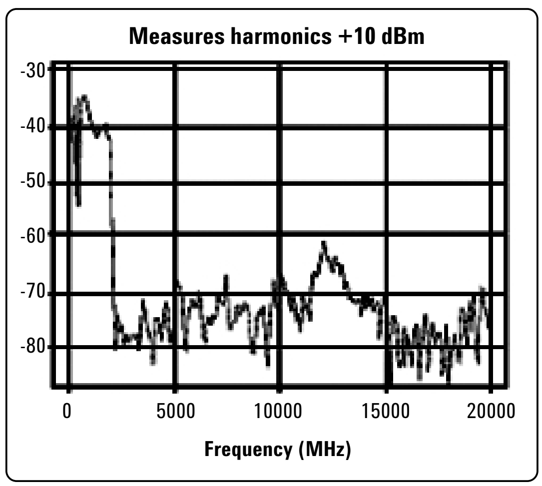

Figure 4b. 40 GHz measured harmonics for E8247/57C PSG CW and analog signal generators

Directional devices

The coupling factor of the reference detector also affects the achievable dynamic range for your scalar measurement. In Figure 2, the "R" channel has a maximum of 76 dB of dynamic range (+16 dBm to –60 dBm). If a +10 dBm source and 10 dB coupler are used, only 60 dB of dynamic range is left in the "R" channel. If a 20 dB coupler is used, the "R" channel can vary over only a 50 dB range, and so forth. The use of a resistive power splitter instead of a coupler before the "R" detector reduces the channel range in a similar way. Since one normally does not use more than 30 dB of "R" channel range, this loss in its range does not usually affect the dynamic range of the setup.

The use of a resistive power splitter instead of a leveling coupler before the "B" detector can also decrease dynamic range. Increasing the output power from the source can compensate for this. For a power splitter (6 dB insertion loss) before the "B" detector, the source would need to provide enough power to achieve the same dynamic range as with a directional coupler with low mainline loss.

Note: if your transmission measurement requires more power than what the source can provide then use an external leveling amplifier in your configuration. The suggested microwave amplifier is the Agilent 8349B. Refer to the appendix section of this application note for the configuration of the gain of an external amplifier to extend the dynamic range of the scalar analysis.

kTB noise and AC detection considerations

Broadband thermal (kTB) noise may affect the sensitivity of any RF or microwave measurement system. Since the thermal noise can reach a level above the maximum sensitivity of these systems, it can limit the minimum signal value that can be detected by the measurement system. Any signal whose magnitude does not exceed the thermal noise floor can be hidden by the kTB.

The Agilent 8757D has AC (modulated RF) detection which provides immunity to thermal noise generated in the system. The AC detection feature provides greater measurement sensitivity for scalar measurements.

The PSG-generated signal is square-wave modulated before passing through any external components of the system. When the output signal is demodulated by AC detection, the modulated signal is detected and the unmodulated thermal noise is not. The 8757D can accurately detect a -60 dBm, 27.8 kHz, square-wave modulated signal in the presence of up to -30 dBm of unmodulated broadband noise.

Measurement accuracy

As with all standard transmission measurements, an accuracy analysis should include the effects of mismatches between the source, the device, and the detectors. Input power limitations of all instruments and components should be observed.

As mentioned earlier, an AC detection system can provide a substantial improvement in the dynamic range by allowing the detectors to ignore unmodulated broadband noise. An AC detection system, however, requires a minimum RF modulation on/off power ratio for accurate measurements. With the Agilent 8757x, 8756A and 8755C, a 30 dB on/off ratio is needed for full accuracy. It is best if the RF can be square-wave modulated by modulating the source internally.

Acknowledgement

The basic idea for extending the dynamic range of a scalar network analyzer was conceived by David Layden, Naval Avionics Center, Indianapolis, Indiana.

Appendix

Using the gain of an external amplifier to extend dyanamic range

Figure 5 shows the configuration for extending dynamic range using an amplifier after the device under test. The dynamic range of this setup is dependent primarily on the maximum unleveled output power of the effective source (PSG) and the gain of the external leveling amplifier. In the example of Figure 5, the effective source is the Agilent PSG signal generator and the leveling amplifier is the Agilent 8349B microwave amplifier.

Extending the frequency of scalar measurements

Using the 83550A series can allow you to extend the frequency range of your scalar measurements up 10 110 GHz.

Performance specifications and typicals for the 83550 series millimeter-wave source modules using the Agilent PSG CW/analog signal generators as the driving source

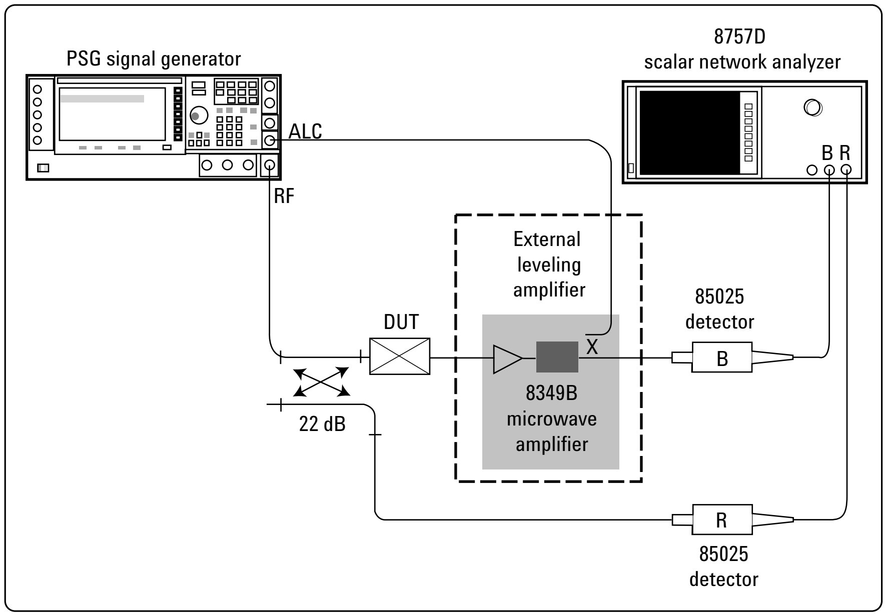

Figure 5. Block diagram of an extended dynamic range configuration using external amplifier

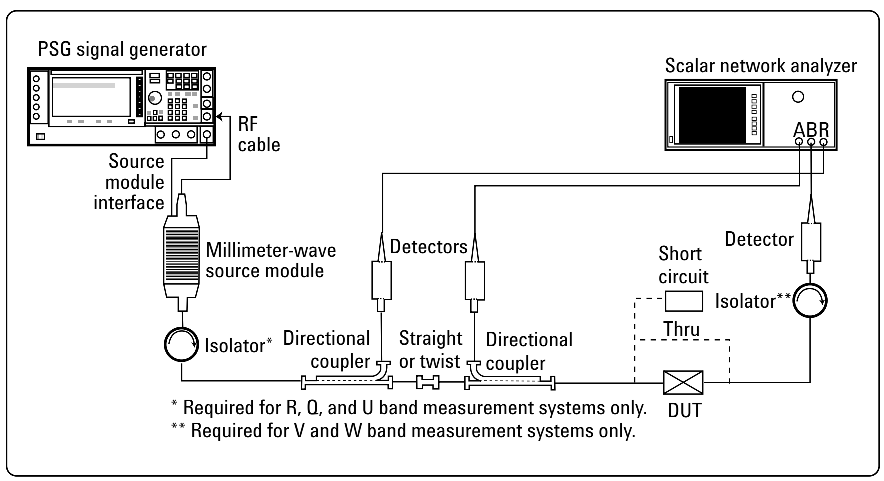

Figure 6. Block diagram for millimeter-wave ratio transmission and reflection measurements

Table 2. 83550 Series millimeter-wave source modules

Agilent PSG signal generators	83554A	83555A	83556A	83557A	83558A
Frequency characteristics					
Range	26.5 – 40GHz	33 – 50GHz	40 – 60GHz	50 – 75GHz	75 – 110GHz
Maximum leveled power	9 dBm	3 dBm	3 dBm	3 dBm	0 dBm
Power level accuracy at 0dBm	±2.0dB	±2.0dB	±2.0dB	±2.0dB	±2.0dB
Power flatness (maximum leveled power)	v1.5dB	±1.5dB	±1.5dB	±2.0dB	±2.0dB
Source output SWR					
Leveled	≤ 2.0dB	≤ 2.0dB	≤ 2.0dB	≤ 2.0dB	≤ 2.0dB
External pulse modulation					
Rise/fall time (typical)	40 ns	40 ns	50 ns	50 ns	50 ns
Minimum RF pulse width					
(typical)	500 ns	500 ns	500 ns	1 us	1 us
On/off ratio (typical)	> 80 dB	> 80 dB	> 80 dB	> 80 dB	> 80 dB
Pulse repetition frequency					
Leveled (typical)	100 Hz – 500 kHz	100 Hz – 500 kHz	100 Hz – 500 kHz	100 Hz – 500 kHz	100 Hz – 500 kHz
Unleveled (typical)	100 Hz – 5 MHz	100 Hz - 5M Hz	100 Hz – 5 MHz	100 Hz – 5 MHz	100 Hz – 5 MHz

Related Agilent Literature

Agilent PSG Signal Generators,
Brochure,
Literature number 5988-7538EN

Agilent E8267C PSG Vector Signal Generator, Data Sheet,
Literature number 5988-6632EN

Agilent E8247C/E8257C PSG Analog/CW Signal Generator,
Data Sheet,
Literature number 5988-7454EN

Agilent 8757D Scalar Network Analyzers, Configuration Guide,
Literature number 5967-6177E

Agilent 8757D Scalar Network Analyzer, Data Sheet,
Literature number 5091-2471E

Agilent PSG Series Product Note: Millimeter Head,
Literature number 5988-2567EN

Agilent Technologies' Test and Measurement Support, Services, and Assistance
Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise
Our Promise means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage
Your Advantage means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and onsite education and training, as well as design, system integration, project management, and other professional engineering services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

Agilent Email Updates

www.agilent.com/find/emailupdates
Get the latest information on the products and applications you select.

Agilent T&M Software and Connectivity
Agilent's Test and Measurement software and connectivity products, solutions and developer network allows you to take time out of connecting your instruments to your computer with tools based on PC standards, so you can focus on your tasks, not on your connections. Visit
www.agilent.com/find/connectivity
for more information.

By internet, phone, or fax, get assistance with all your test & measurement needs

Phone or Fax

United States:
(tel) 800 452 4844

Canada:
(tel) 877 894 4414
(fax) 905 282 6495

China:
(tel) 800 810 0189
(fax) 800 820 2816

Europe:
(tel) (31 20) 547 2323
(fax) (31 20) 547 2390

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Korea:
(tel) (82 2) 2004 5004
(fax) (82 2) 2004 5115

Latin America:
(tel) (305) 269 7500
(fax) (305) 269 7599

Taiwan:
(tel) 0800 047 866
(fax) 0800 286 331

Other Asia Pacific Countries:
(tel) (65) 6375 8100
(fax) (65) 6836 0252
Email: tm_asia@agilent.com

Online Assistance:
ww.agilent.com/find/assist

Product specifications and descriptions in this document subject to change without notice.

Printed in USA, April 15, 2003
5988-8432EN

Agilent Technologies