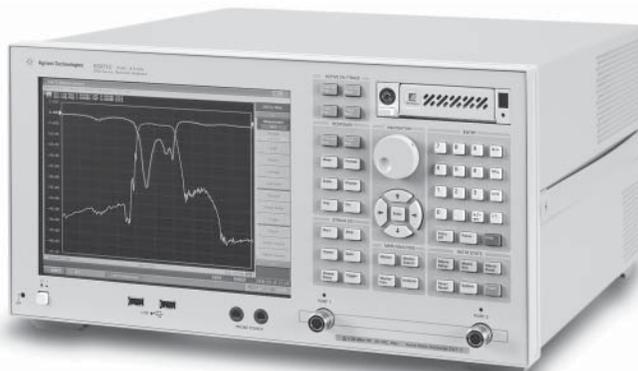


7 Reasons to Upgrade from your 8753 to an ENA Network Analyzer

Application Note 1478

- Superior performance and speed
- Enhanced usability
- Expanded error correction capabilities
- Easy and accurate multiport measurements
- Code conversion assistant tool
- Highly accurate mixer measurements
- Enhanced upgrade and data security capabilities



Agilent Technologies

Overview

Many 8753x users have replaced their analyzers with the ENA since its introduction in November 2001. Although the reasons for making this change to some extent depend on the customer's particular situation, it is easy to highlight the ENA features that are most highly valued by our customers. This document tries to help 8753x users understand how the ENA can improve their network measurement environment, especially in applications related to RF component production tests.

1. Superior Performance and Faster Speed

The ENA provides significantly better measurement performance than the 8753ES in terms of dynamic range and trace noise, which allows you to improve test quality. The difference appears very obvious in the dynamic range and trace noise comparisons shown in Figures 1 and 2.

Measurement speed is critically important in production lines, where test throughput is the most significant factor in the cost of a test. The ENA, with its superior basic measurement performance, sweeps much faster than the 8753ES at the same level of dynamic range or trace noise.

Figure 3 shows a comparison of sweep speed in the production test of a high-performance base station filter, which requires very low trace noise for testing the pass-band flatness and very wide dynamic range for testing the deep rejection levels. As shown in this example, the ENA provides much faster speed, allowing you to dramatically improve test throughput.

Also, in a high-volume automated production test environment, the ENA offers extremely fast sweep speed with a very wide IF bandwidth (9.6 us/point at 100 kHz IFBW). Figure 4 shows a sweep speed comparison for a SAW filter automated production test.

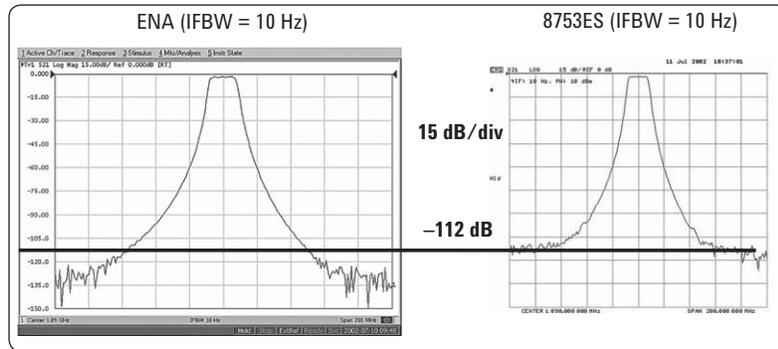


Figure 1. Maximum dynamic range comparison

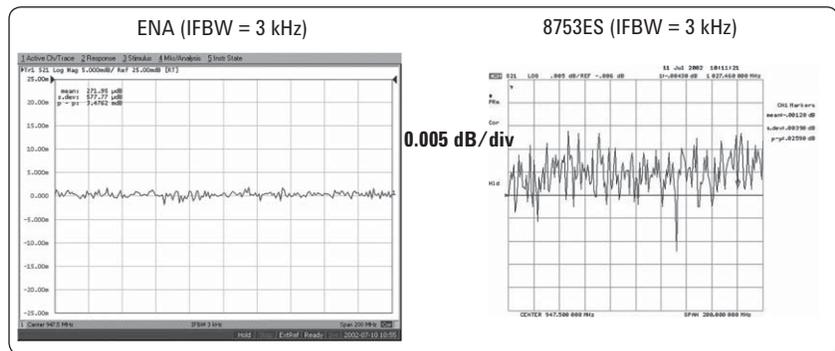


Figure 2. Trace noise comparison

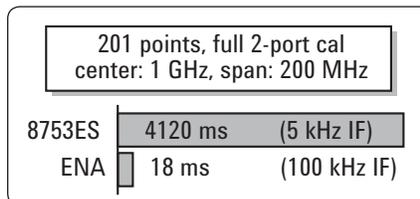


Figure 3. Speed comparison at 0.01 dB p-p trace noise

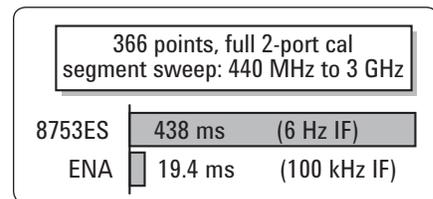


Figure 4. Speed comparison in high-volume manufacturing

2. Enhanced Usability

Similar look and feel to 8753x

It is difficult to fully describe the value of the ENA's enhanced usability. However, it has been enthusiastically adopted by many 8753x users, who tend to be reluctant to accept a new user interface because they are very familiar with the 8753x. Actually, the ENA's user interface is based on the 8753x, with several improvements that mainly allow the Windows®-like interface to work much better than the traditional analyzer interface. For example, it is much easier to set up a limit line table by using a spreadsheet. A touch screen makes interactive operation even easier.

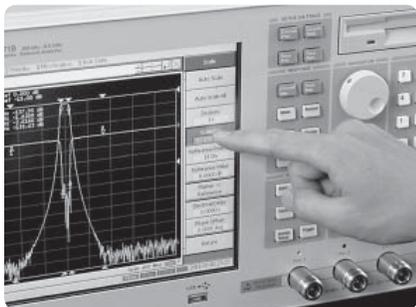


Figure 5. Similar user interface to 8753x plus a touch screen

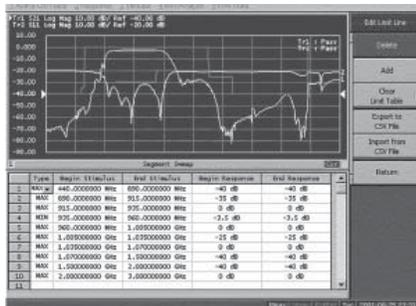


Figure 6. Setting limit line using spreadsheet

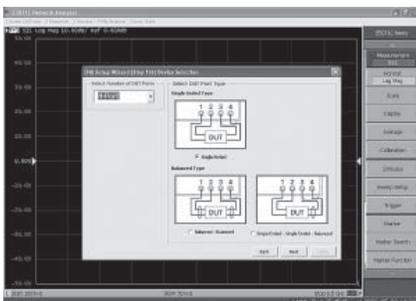


Figure 7. ENA setup wizard

Built-in VBA and sample Wizard programs

The ENA is equipped with Visual Basic® for Applications (VBA), which allows you to create and run a macro within the analyzer. You can further improve usability by making VBA programs to automate your operation sequences. Various sample Wizard programs are available for easy measurement setup. Figure 7 shows the ENA setup wizard, which is an example of the sample wizard programs.

For more details, visit <http://www.agilent.com/find/enavba>

Embedded Help and Open Windows® Operating System.

Online help and Open Windows operating system support easy-to-learn operation and efficient data collection. When you have a question, just press "HELP" on the front panel, and you'll get the necessary information with ease. Also, you can easily save measurement data to USB memory devices.

LAN connectivity

LAN connectivity, in addition to GPIB, offers you an easy analyzer connection to your network environment. You can build a centralized production line by using the ENA's LAN connection. Figure 9 shows an example of factory automation with the ENA.

- You can directly save the measured data from the ENA to the server through a LAN.
- You can download measurement programs from the host computer to the ENA.
- The actual measurement process can be carried out locally by using the VBA programs on the ENA.



Figure 8. Windows open operating system.

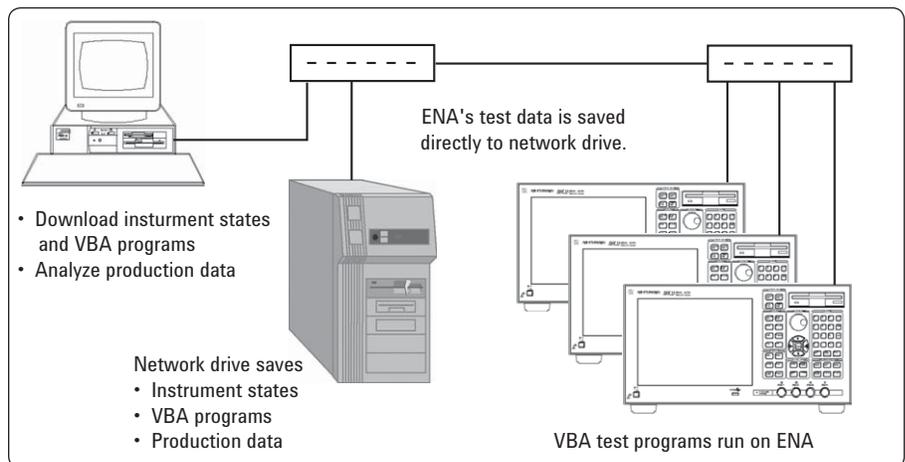


Figure 9. ENA factory automation example

Web-enabled control

For distributed teams, simply setup the ENA on your LAN, and users can access the instrument from any Java™-enabled Web browser. You can easily capture screen shots for a report, or control the ENA from a remote location without using special software.

Easy connection to an external PC

A USB (USBTMC)¹ interface lets you easily connect the ENA to a PC controller via a USB cable. The ENA can be easily controlled via the USB interface with Agilent VEE 7.0 or Agilent I/O library suite.

8753 compatible limit test functions

For 8753x users who are doing limit-line tests, the ENA provides the following limit-line functions that enable you to perform the 8753x compatible limit-line testing.

- Offset limit-line function adjusts offset values to the frequency and magnitude level.
- Ripple limit test can define the start and stop frequencies, as well as the maximum allowable ripple value of each frequency band. This test allows you to set up as many as 12 frequency bands for testing ripple.
- Bandwidth limit test can define the amplitude below the peak and the minimum and maximum allowable bandwidths.

Wide frequency and sweep range

The ENA's wide frequency range (9 kHz to 20 GHz with 6 options) provides better visibility of DUT frequency characteristics.

Also, a wide 65 dB² power sweep range enables you to check the characteristics of an active device under different power ranges with ease.

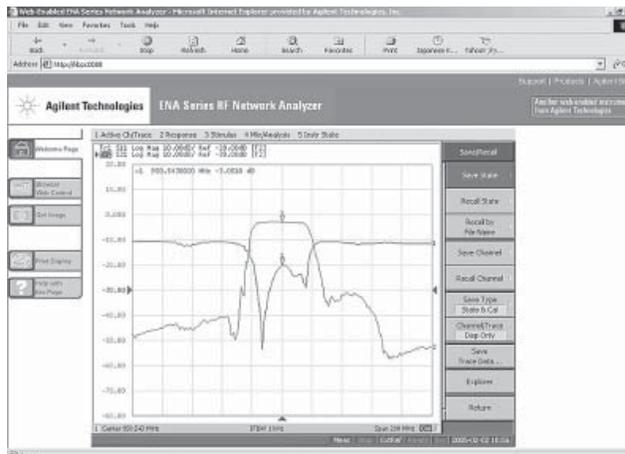


Figure 10. Web-enabled control

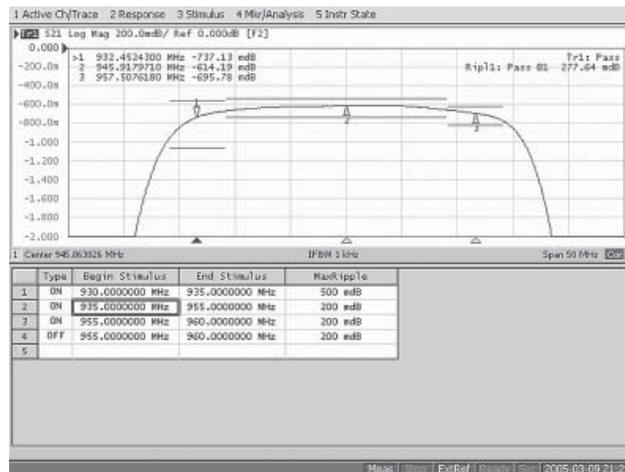


Figure 11. Ripple limit test

1. USB Test and Measurement Class (TMC) interface that communicates over USB using USBTMC messages based on the IEEE 488.1 and IEEE 488.2 standards. This interface is supplied with E5071C ENA network analyzers and with E507xB ENA network analyzers that have serial numbers starting with MY424.

2. Options x4x, x8x only.

3. Expanded Error Correction Capabilities

Full 3- and 4-port calibration

Conventional network analyzers test multiport devices with a combination of 2-port calibrations by using several measurement channels. However, this calibration method may cause measurement errors due to unwanted reflections at uncorrected device ports, especially in the case of low-loss and non-isolated multiport devices such as directional couplers. The ENA can solve this problem with full 3- and 4-port calibrations. The example in Figure 12 shows the advantage of full 3-port calibration in a directional coupler measurement.

Mixed-connector calibration using adapter characterization

The ENA offers a new approach to non-insertable and mixed-connector device measurements, which are relatively common in base station component tests. Figure 13 shows the concept of the ENA's mixed-connector calibration with the adapter characterization technique. This technique is much easier than the 8753x's adapter removal technique, particularly in mixed-connector multiport device measurements, and it provides equivalent accuracy.

Adapter characterization

The ENA's adapter characterization function calculates an adapter's 2-port S-parameters from three S11 measurement results by terminating the other end of the adapter with the open, short, and load standards.

The adapter is considered the signal flow model, as shown in Figure 14, and three unknown parameters (E_{df} , E_{sf} , and E_{rf}) are derived from the S11 measurements with open, short, and load terminations. This function allows you to characterize the through adapters used for mixed-connector calibrations.

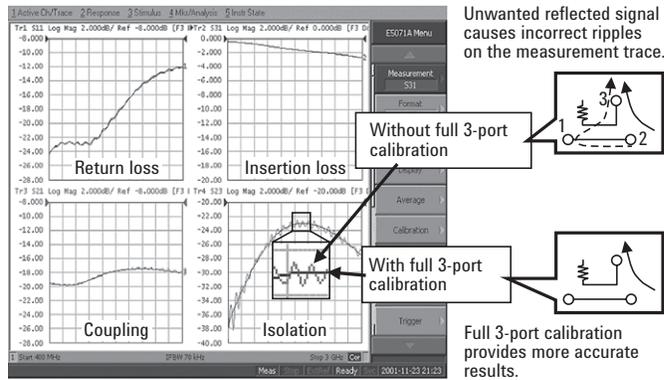


Figure 12. Full 3-port calibration in coupler measurement

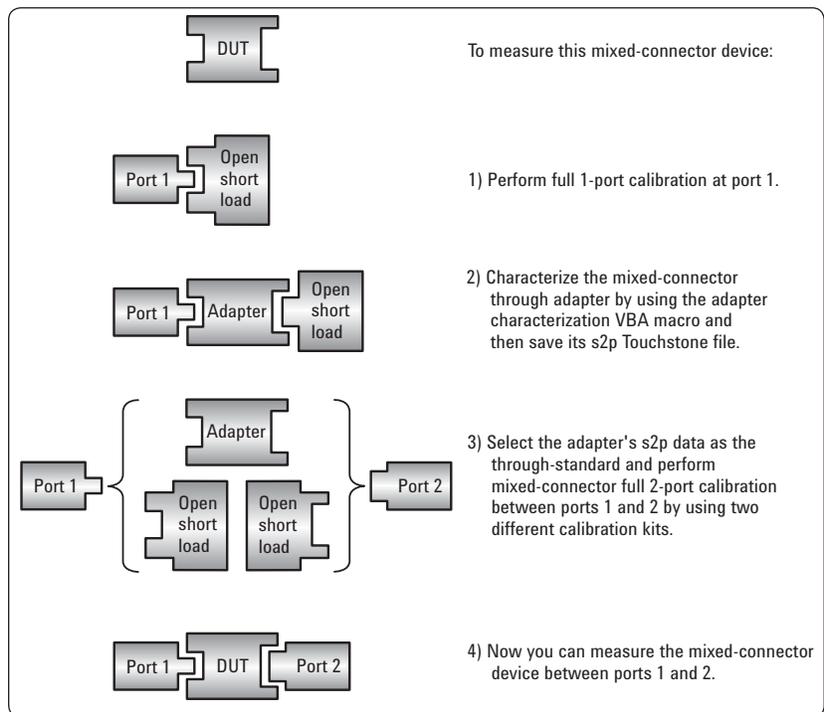


Figure 13. Mixed-connector calibration using adapter characterization (in the case of 2-port measurement)

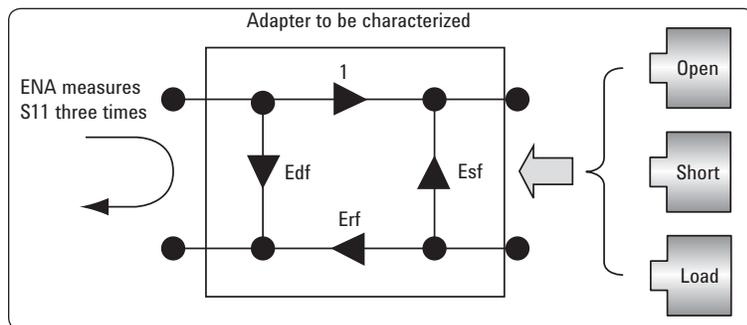


Figure 14. Adapter characterization (single directional method)

Accessible calibration coefficients

Like the 8753x, the ENA offers easy read/write calibration coefficient capability through programming commands. This function enables you to apply your own system error correction to the ENA.

TRL/LRM and waveguide calibrations

Unlike the 8753x, the ENA provides true TRL/LRM calibration which is a useful calibration method for non-coaxial device measurements. The ENA extends TRL/LRM calibration to 3- and 4-port error correction, which enables accurate non-coaxial multiport measurements.

In addition, the ENA supports waveguide calibration like the 8753x. For waveguide calibration, Agilent recommends Maury Microwave products. Maury Microwave is an Agilent channel partner that provides the best suited waveguide calibration kits¹ for the ENA.

Adapter removal and insertion

The ENA has enhanced adapter removal/insertion capability for accurate mixed connector, multi-port calibration. Traditional adapter removal requires two full two-port calibrations (14 connections); the ENA's enhanced adapter removal/insertion only requires one full two-port calibration and one full one-port calibration (10 connections). This reduces multi-port adapter removal/insertion time significantly.

Automatic port extension

The 8753x provides a port extension feature, but it cannot compensate the insertion loss of a test fixture. The automatic port extension (APE) on the ENA, however, provides a solution for a complex test environment. APE not only enhances port extension by compensating for both electrical delay and insertion loss, but it also simplifies the approach such that the user no longer needs to provide accurate calibration standards. Instead, a "blank" fixture can be used as the open standard to characterize the fixture.



Figure 15. Maury Microwave Waveguide calibration kit

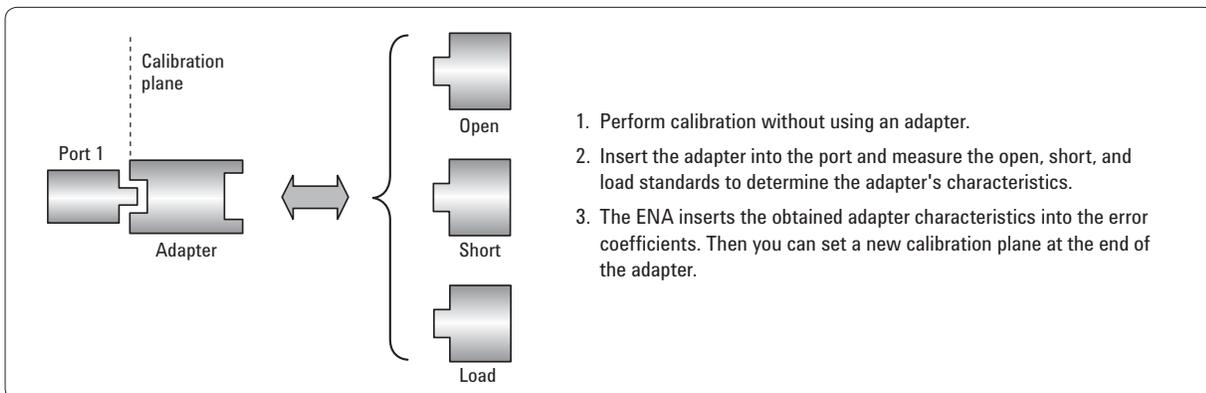


Figure 16. Enhanced adapter removal and insertion

1. For more information regarding Maury Microwave waveguide calibration kits visit: www.maurymw.com.

ECal for automatic calibration

The ENA supports 2-port and 4-port Electronic Calibration (ECal) modules. The ECal module automatically performs the calibration procedure. You can make complicated full 2-, 3-, and 4-port calibrations with a single connection minimizing operational errors.

User-characterized ECal

The ENA's user-characterized ECal function is for characterizing 2-port and 4-port ECal modules with adapters connected to their ports. You can customize your ECal module by connecting adapters that match your device's connector type. The typical characterization procedure is as follows:

- 1) Calibrate the ENA with a mechanical calibration kit. In the case of mixed-connector device measurements, perform mixed-connector calibration using the adapter characterization technique.
- 2) Measure the ECal module with adapters using the calibrated ENA.
- 3) The ENA stores the measured data into the user area of the ECal's built-in memory as user-defined ECal data.

ECal confidence check

The ECal confidence check function allows you to check whether the correct measurement is possible after performing the ECal. The ENA measures the S-parameters of an ECal module set to a special verification state, this allows you to compare the current S-parameter measurement data of the ECal (displayed in the data trace) with the reference "golden" data recalled from the ECal's internal memory (displayed in the memory trace). The ECal confidence check helps you to detect incorrect calibrations due to cable misconnections, among other causes, and improve measurement reliability.

Unknown Thru (through) Calibration

Unknown thru calibration is the preferred through method of calibrating the ENA to measure a non-insertable device. The major benefits of using a unknown thru calibration are:

- easy to perform
- provides better accuracy than defined thru and is usually better than adapter removal
- does not rely on existing standard definitions that may no longer be accurate.
- causes minimal cable movement if the thru standard has the same footprint as the DUT. In fact, the DUT can often be treated as the thru standard.



Figure 17. N4431B 4-port ECal module

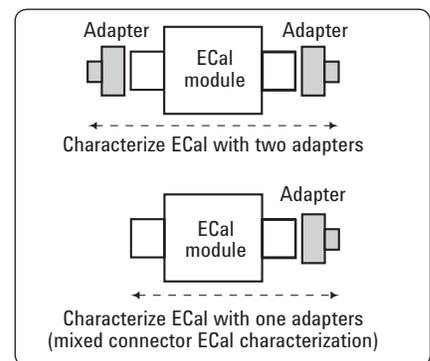


Figure 18. User characterized ECal examples

De-embedding for removing test fixture effects

When measuring non-coaxial devices such as SMDs, it is necessary to use a test fixture to connect the device to the analyzer. A simple way of removing the fixture effects is to perform calibration of coaxial test cables and use a port extension to extend the measurement planes (calibration planes) toward the device planes, based on the assumption that the fixture has 50-ohm transmission lines. When this assumption cannot be satisfied, the ENA's de-embedding function is a more suitable solution. The de-embedding function mathematically removes the 2-port (or 4-port) networks defined as Touchstone s2p (or s4p) S-parameter data files.

To perform fixture de-embedding, it is necessary to characterize the fixture's transmission lines and get their Touchstone S-parameter data files. There are two possible ways to characterize the fixture.

- Mathematically characterize the fixture using software simulation tools such as the Agilent Advanced Design System (ADS).
- Characterize the fixture directly by measuring it with the ENA and an RF probe station.

For more information on fixture characterization, refer to the Product Note E5070/71-4, "In-fixture characterization using the ENA with Cascade Microtech Probing System" (PN 5988-9463EN).

In addition, the de-embedding function enables mixed-connector device measurements in a different manner than the mixed-connector calibration approach shown in Figure 20. You can remove the effects of the adapter connected to the calibration plane by using the de-embedding function. The adapter's S-parameter file can be obtained by using adapter characterization.

Embedding virtual networks

The ENA also has an embedding function, which is the inverse operation of de-embedding. This function allows you to test the devices by virtually connecting networks, such as matching circuits and other devices that are connected in the actual circuits of final products. You can set the embedding data by entering the values of pre-defined matching circuit models (Figure 22) or using the Touchstone S-parameter data files.

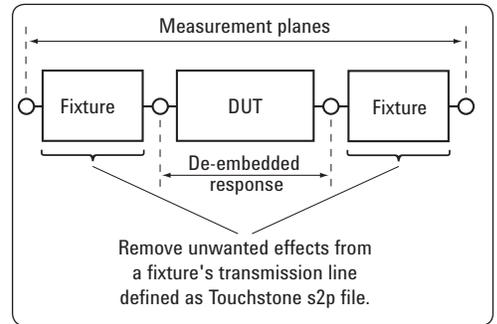


Figure 19. De-embedding for removing fixture effects

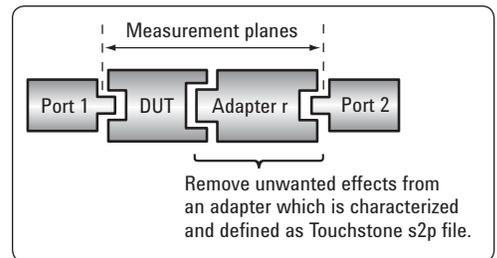


Figure 20. De-embedding for mixed-connector device measurements

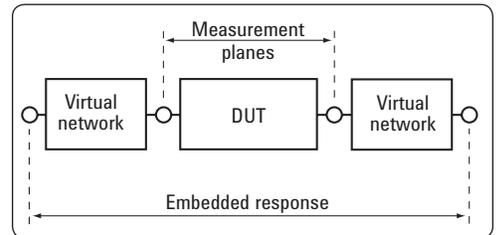


Figure 21. Embedding virtual networks

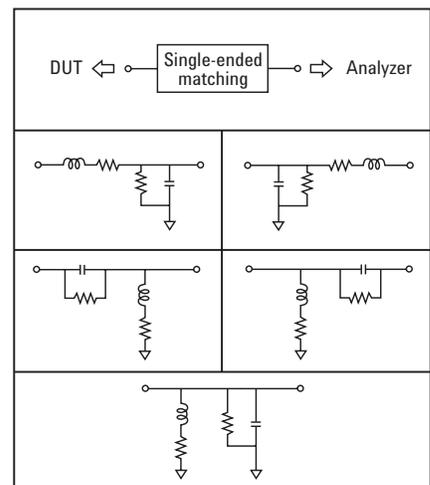


Figure 22. Pre-defined models of matching circuit embedding

4. Comprehensive Multiport Solution

The ENA offers 2- or 4-port options with various frequency ranges (4.5 GHz to 20 GHz). One of the notable advantages of the ENA multiport solution over the 8753x is its easy operation. Unlike the 8753 family which is fundamentally a 2- or 3-port analyzer, the 4-port ENA was designed for multiport measurement with an 8-receiver architecture. This makes the multiport ENA much easier to use. The 4-port ENA can perform 4-port SOLT or TRL calibration for more accurate characterization of the DUT.

In addition, multiport test sets such as the E5092A, are designed specifically for the ENA to increase the number of test ports and enable efficient characterization of multiport devices with a single connection.

Flexible multiport measurement

The ever increasing and changing demands of applications are changing multiport device measurement requirements. Designers and manufacturers need multiport solutions that cover a wide variety of measurement applications. The E5092A configurable multiport test set works with the ENA to provide unlimited combinations of measurement configurations to meet the measurement requirements of multiple applications. Multiple multiport measurement configurations, from 50 MHz to 20 GHz, can be made by connecting cables to the E5092A's front panel which accesses the test set's internal switches.

Figure 24 shows the block diagram of the 22-port configuration for the E5092A. External cables are connected to the E5092A's front panel expanding the 4-port ENA to a 22-port measurement configuration (Figure 25).

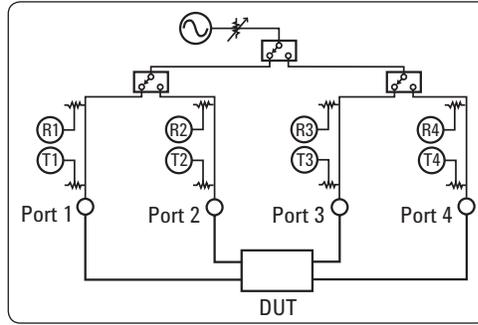


Figure 23. 4-port ENA hardware architecture

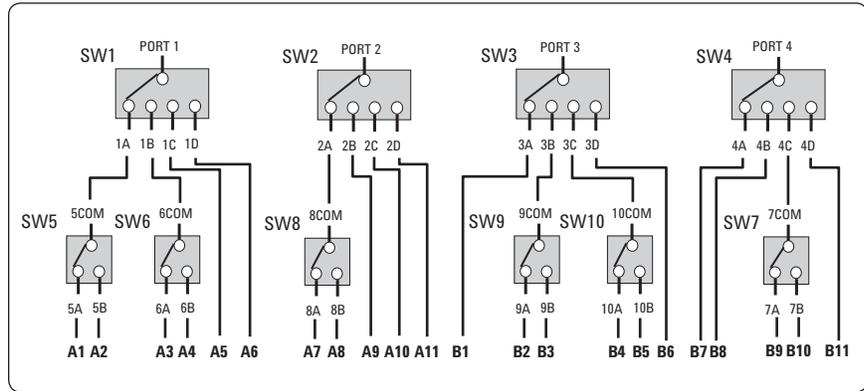


Figure 24. Block diagram of 22-port configuration



Figure 25. 22-port configuration showing external cable connection

Another configuration example using the ENA and E5092A is shown in Figure 26. This configuration provides up to a 10-port, full crossbar measurement. This allows a 2-port measurement to be performed on any port of the test set. This configuration is most suitable for multipoint components which require full matrix measurements for characterization. Figure 28 shows the connectivity matrix for this configuration.

Also you can control up to two E5092As from a single 4-port ENA. This enables multipoint characterization for up to 40 ports.

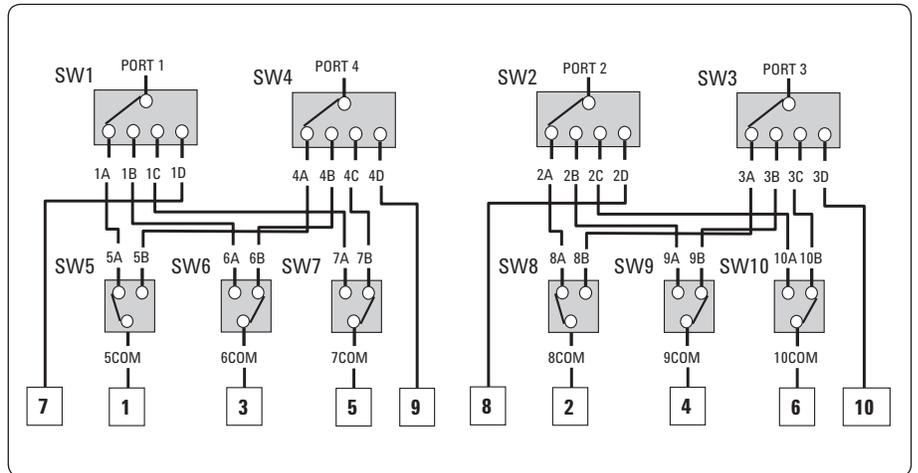


Figure 26. Block diagram of 10-port full crossbar configuration

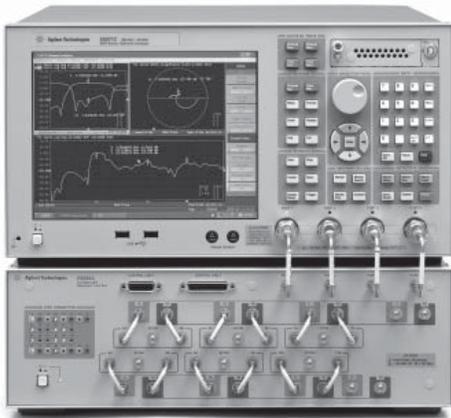


Figure 27. Connection of external cables for a 10-port full crossbar configuration

Src/Rcv	1	2	3	4	5	6	7	8	9	10
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 28. Measurement matrix for 10-port full crossbar configuration

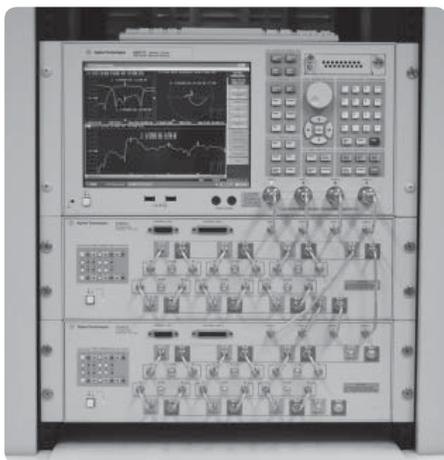


Figure 29. Two E5092A configurable test sets cascaded

Measurement Wizard Assistant (MWA) Software

For multiport network analysis, measurement setup time usually takes much longer than the actual testing. The ENA's Measurement Wizard Assistant (MWA) software simplifies the setup of complicated measurements. MWA software assists not only with complex measurement parameter setups such as the segment sweep, limit testing, and calibration but also enables system control via the ENA I/O port.

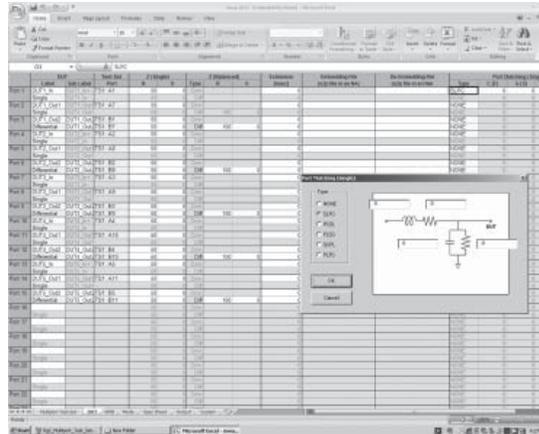


Figure 30. The Excel-based user interface provides a "Step-by-step" setup wizard

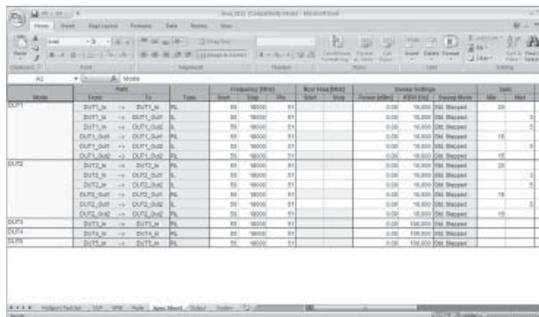


Figure 31. One setup file (.mwa) includes all measurement parameters

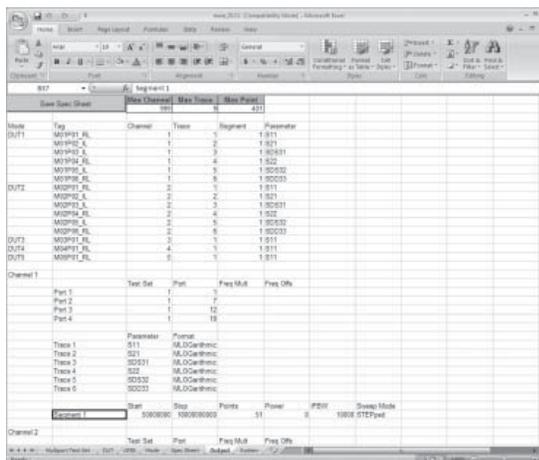


Figure 32. Easy and fast setup of multiport measurements for the ENA

After you enter the necessary measurement parameters, the MWA software automatically generates a setup file. Then, all you have to do is load the setup file into the ENA and start complex measurements immediately.

The MWA software's step-by-step calibration wizard controls the whole measurement procedure dramatically reducing your measurement setup and operation times.

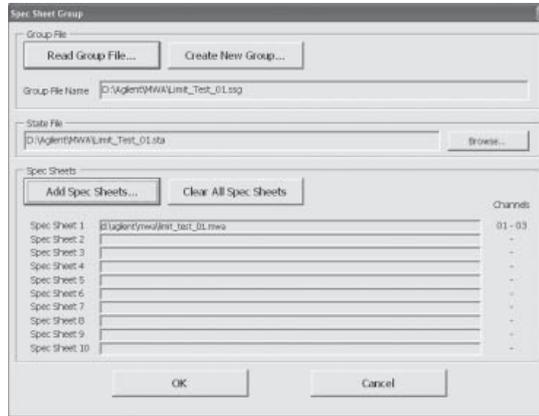


Figure 33. The .mwa setup file sets all the measurement parameters on the ENA automatically

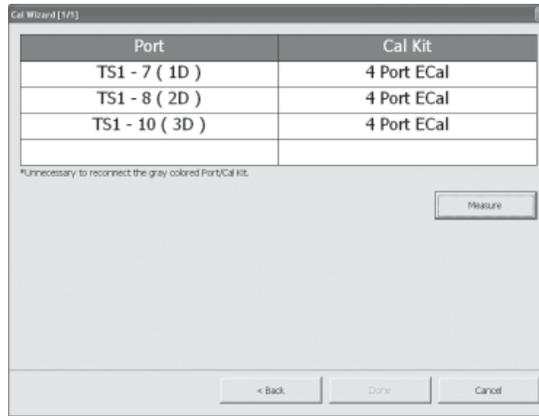


Figure 34. A calibration wizard minimizes operating time.

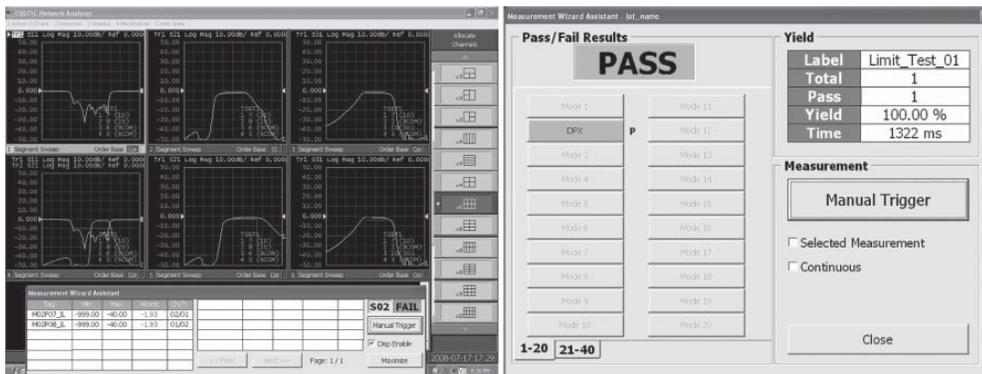


Figure 35. Automatic test procedures provide go/no go limit testing

5. Highly Accurate Mixer Measurements

Unlike the 8753x, the ENA provides vector- and scalar-mixer calibration techniques that enable you to perform highly accurate mixer measurements.

Advanced mixer calibration techniques

The ENA offers frequency-offset mode¹ (FOM) which provides frequency-offset sweep, external signal source control, and fixed IF/RF measurement capabilities. In addition, FOM supports two mixer calibration techniques. The first is vector-mixer calibration (VMC) which corrects for directivity, source match, load match, and reflection frequency response at each test port by using a characterized calibration mixer with de-embedding function. This calibration technique provides the most accurate measurements of phase and absolute group delay. The second, is the scalar-mixer calibration (SMC) technique which offers the highest accuracy conversion loss/gain measurement results by correcting the mismatches of both input and output test ports.

Harmonics measurements for non-linear devices

FOM also provides harmonics measurement capabilities for non-linear device evaluation. By combining the frequency-offset sweep and receiver calibration with power-meter, the ENA performs fast and accurate absolute magnitude measurements the same as a spectrum analyzer.

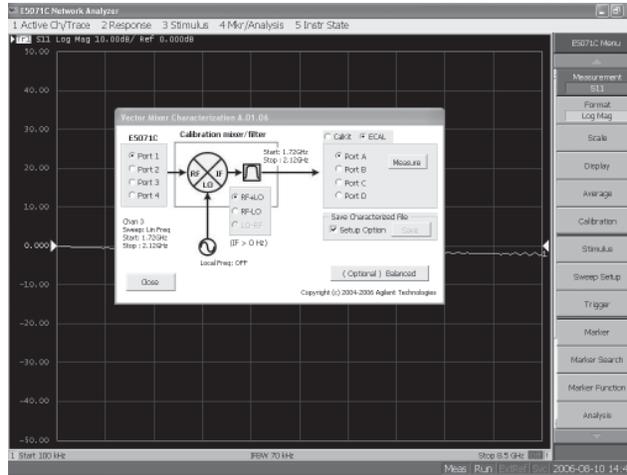


Figure 36. Vector-mixer calibration using VBA

1. Option 008 is required.

6. Code Conversion

Code conversion challenges

To replace the 8753x, which is automated with an external PC, it is necessary to rewrite the 8753x's programs for the ENA. However, there are some difficulties when converting the programs. First, programmers have to find appropriate GPIB commands from the large number of ENA GPIB commands. Second, it is difficult for programmers to know if a selected ENA GPIB command is the best choice. If programmers have to convert many 8753x programs, it will be very time-consuming work.

Blue command

There is only one equivalent GPIB command.

Yellow command

There are multiple GPIB candidate commands.

Red command

There is no equivalent GPIB command.

8753-to-ENA code conversion assistant editor

The 8753-to-ENA code conversion assistant editor helps to convert 8753x GPIB commands. This software consists of a text editor (EmEditor¹) and plug-in software, which works on a PC and makes it easier to edit programs in text file format.

When loading the 8753x's program, its GPIB commands are categorized into blue/yellow/red commands according to the complexity of the code conversion work required (Figure 37).

A "blue" command can be easily converted to the equivalent ENA GPIB command.

A "yellow" command requires some consideration, and Quick Help provides a brief command description and conversion choices.

A "red" command means there is no equivalent ENA GPIB command. The code conversion assistant editor helps avoid unnecessary work.

How to convert blue commands

The code conversion assistant editor can convert multiple blue commands at the same time. By specifying the range and clicking the NA button, the 8753x GPIB commands can be directly replaced by the ENA GPIB commands without typing (Figure 38). This editor speeds up code conversion work significantly. It must be noted that the editor is not a real-time converter like a software emulator that works on the ENA.

Figure 37. Definition of blue/yellow/red commands

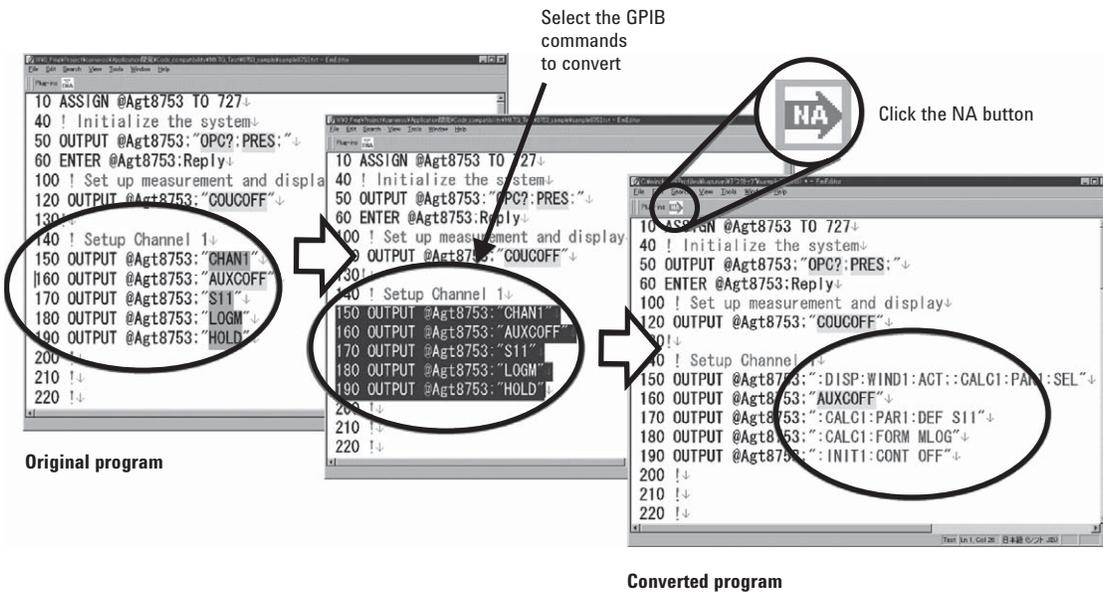


Figure 38. How to convert blue commands

1. EmEditor is shareware provided by Emursoft <http://www.emursoft.com>

Quick Help shows the best way to convert code

When converting a “yellow” command, Quick Help shows the ENA’s candidate commands (Figure 39), and programmers chose the appropriate one. If a direct replacement command doesn’t exist, alternative solutions are displayed in the text box. For a “red” command, the Quick Help explains why the GPIB command cannot be converted. Quick Help enables you to succeed in code conversion work without confusion.

Multiple program languages

The code conversion assistant editor supports multiple program languages. Basically, text-based program languages are supported; for example, C/C++, HT BASIC and Visual Basic. If a VEE program is saved as a text file, 8753x GPIB commands can be converted with this Code Conversion Assistant Editor.

Limitations of code conversion assistant editor

We recommend that you write the corresponding part of a program from scratch instead of converting the commands related to these functions:

- Trigger system
- Limit line and segment sweep table setup
- Calibration
- Status monitor

Since the concepts of these functions are different between the 8753x and the ENA, we cannot easily replace the corresponding 8753x GPIB commands. When you try to convert these commands, Quick Help guides you to the relevant section in the ENA Programmer’s Guide.

The code conversion assistant

The editor consists of a text editor (EmEditor) and plug-in software. You can download both of them from <http://www.agilent.com/find/ena>. The plug-in is free and the EmEditor is shareware provided by Emurasoft. To use it more than 30 days, users must register with Emurasoft, not with Agilent Technologies. For more information, refer to “How to register” in the help menu of the EmEditor.

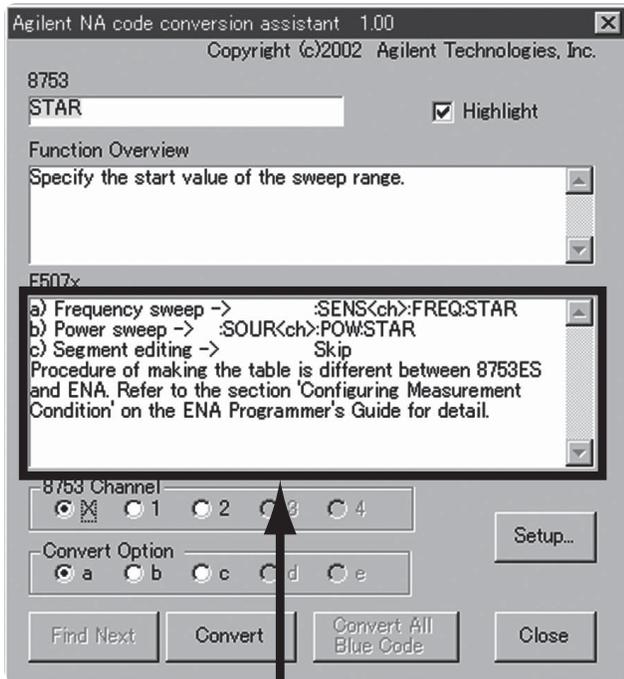


Figure 39. Quick Help shows equivalent GPIB commands and code conversion tips

7. Enhanced upgrade and data security capabilities

If you are using the 8753x in a secure area, in order to protect your data, the ENA offers equivalent and more advanced security operation.

Upgrade options protect your hardware investment

The E5071C ENA is a safe investment because of it is easy to upgrade. Upgrade software or hardware features whenever you need them. Software options such as time-domain mode, frequency offset mode, and MWA, and hardware options such as maximum frequency, test-port, and high stability time base are fully upgradeable.

Confidential data protection

Since it is virtually impossible to completely or selectively erase all user data on a hard disk without destroying the operating system, the best method for maintaining security when the ENA is not in a secure area is to remove the hard disk drive. The ENA provides the removable hard disk drive as an optional feature; enabling you to easily remove the drive and keep it safe in a secure area.

Secure operation

In order to protect confidential data, the ENA can disable access to the information on its hard disk via the LAN and USB mass storage devices. In addition, the frequency blanking function allows you to completely hide the displayed frequency parameters. Using the ENA security functions, it's easy to protect classified data and measurement parameters, which are not to be viewed by unauthorized personnel.



Figure 40. Removable hard disk drive allows you to secure and protect your confidential data

ENA/8753ES Comparison table

Item	E5071C Option 240/245/440/445	E5071C Option 280/285/480/485	E5071C Option 2K5/4K5	8753ES
Test frequency	9 or 100 kHz to 4.5 GHz	9 or 100 kHz to 8.5 GHz	300 kHz to 20 GHz	30 kHz to 6 GHz
Source power range ¹	-55 dBm to +10 dBm		-85 dBm to +10 dBm	-85 dBm to +10 dBm
Dynamic range	> 123 dB			110 dB
Trace noise	< 0.004 dBrms			0.006 dBrms
Measurement speed ²	41 ms			848 ms
Stability	0.005 dB/degree C			0.03 dB/ degree C
Interface	GPIB/LAN/USB			GPIB
Test port	2- or 4-port			2- or 3-port
Max number of points	20,001			1,601
Max number of channels	160			2
Calibration	SOLT, TRL, Adapter removal/insertion, Unknown thru, ECal, User characterized ECal, SMC, VMC			SOLT, TRL*, Adapter Removal
Web-enabled control	Yes			No
Operating system	Open Windows®			Closed
Fixture simulator	Yes			No
Built-in programming environment	VBA			No
Future enhancements / upgradeability	Yes			No
Filter tuning limit lines	Yes			Yes
Built-in bias tees	Yes			Yes
Probe power	Yes			Yes
DC measurements	Yes			Yes
Frequency offset mode option	Yes			Yes
Time-domain option	Yes			Yes

For more detail, refer to the ENA Data Sheet, literature number 5989-5479EN.

1 Maximum output power is changed according to measurement frequency.

2 1601 points, full two-port calibration, 1 GHz to 1.2 GHz, IFBW = 500 kHz (E5071C), 6 kHz (8753ES).

Web Resources

Visit our Web sites for additional production information and literature.

ENA network analyzers:
www.agilent.com/find/ena

Electronic calibration (ECal) modules:
www.agilent.com/find/ecal

Test and measurement accessories:
www.agilent.com/find/accessories

For addition information regarding Maury Microwave waveguide calibration kits visit:
www.maurymw.com

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