HP 8510 8720 NEWS

HEWLETT PACKARD
Expanding Possibilities

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Making VNA measurements above 110 GHz

Bud Noren,
Custom System Specialist,
HP's Santa Rosa
Systems Division

You can now make vector network analyzer measurements in waveguide at frequencies up to 220 GHz using the HP8510C VNA. Previously, S-parameter measurements above 110 GHz required the user to develop the equipment necessary for multiplication to the desired frequency, signal separation, and finally downconversion to the IF required by the VNA. The HP 85106D E12 system—in conjunction with components supplied by two other vendors—greatly simplifies this process. The system as shown here can function in two modes: one which uses the external waveguide test modules to make millimeter wave measurements, and one in which the system functions as a standard 50 GHz coaxial system.

What you need

Figure 1 shows the basic elements of the system. (Not shown are cables and power supplies.) All components shown are supplied by Hewlett-Packard as part of the HP 85106D E12 test system, except the two waveguide test modules shown in gray on the system worksurface.

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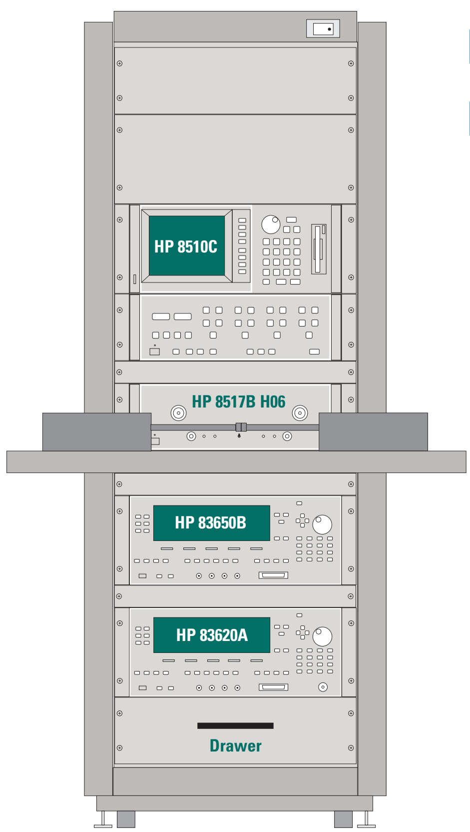

Figure 1. The HP 85106D E12 system with OML test modules.

Also in this issue

More details on page 12

Continued from previous page

These test modules are supplied by Oleson Microwave Laboratories (OML) of Morgan Hill, CA. Currently, OML produces test modules in WR08 (90–140 GHz), and WR05 (140–220 GHz). TRL calibration devices are also required. These may be obtained in any of the above bands from Aerowave Inc., of Medford, Massachusetts. See Product Note 8510-8A, *Applying the HP 8510 TRL Calibration for Non-coaxial Measurements*, publication #5091-3645E, for details on this calibration technique.

Figure 2. The HP 8517B H06 Test Set serves as the interface between the HP 8510C VNA and the OML high-frequency test modules.

How does it work?

Millimeter wave measurements are accomplished by using the OML test modules in conjunction with the HP 85106D E12 microwave subsystem. The interface to the HP 8510C is made through the HP 8517B H06 test set, shown in Figure 2. A standard HP 8517B test set may be retrofitted with option H06. When the HP 85106D E12 system is connected to a pair of OML high-frequency test modules, the system is capable of functioning in two modes: the HP 8517B (50 GHz coaxial) mode and the External Converter mode. The frequency coverage in the External Converter mode will depend upon which OML test modules are connected. The mode of operation is selected by means of a mode switch on the front panel of the test set.

Typical system performance is shown in Table 1 for the HP 85106D E12 system when used with a pair of OML WR08 (90–140 GHz) test modules.

Typical Performance with WR08 Modules

Port Power	Dynamic Range	Raw Directivity	Raw Match	Residual Directivity	Residual Match
–10 dBm	75 dB	35 dB	17 dB	50 dB	50 dB

Table 1. Typical performance of the HP 85106D E12 system with WR08 modules.

Who to contact

Oleson Microwave Laboratories
355 Woodview Dr. Suite 300
Morgan Hill, CA 95037
Tel: (408) 779-698
Email: oml@pacbell.net
Web: http://olesonmicrowave.com

Aerowave, Inc.
344 Salem St.
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Tel: (781) 391-1555
Fax: (781) 391-5338 ■

“*Today's leading technologies are moving towards higher frequencies even beyond 110 GHz.*”

Now available: Custom frequency converter test system for the satellite and LMDS market

My Le Truong, Market Development Engineer, HP's Microwave Instruments Division

Designed specifically for the unique needs of the expanding satellite and LMDS market, the new HP Z2005A/H92 system provides superior measurement accuracy for frequency-translation devices such as mixers and frequency converters. The system is most valuable for designers, manufacturers, and system integrators of communication systems (such as telemetry applications, satellite and LMDS) in which high-accuracy group delay measurements are of great importance.

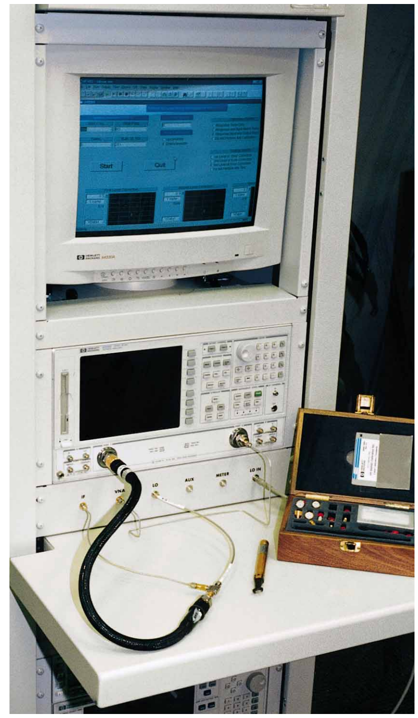
Using vector-error correction to measure these challenging devices, the custom HP system achieves highly accurate and low-ripple measurements of magnitude and phase. Absolute group delay accuracy is specified at an impressive ±150 ps, whereas alternative techniques may have typical accuracy of a few ns.

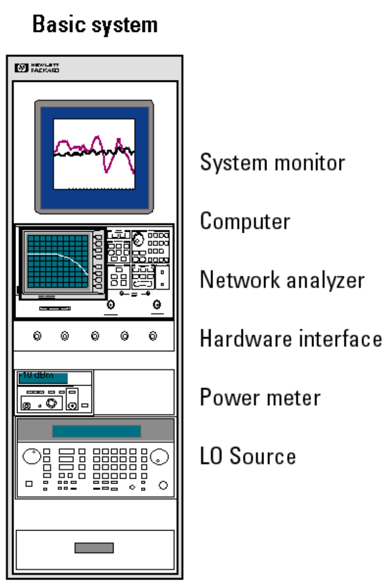
Advanced measurement technique

This advanced absolute group delay measurement technique uses a mixer calibration standard and vector error correction to achieve high-precision absolute group delay measurements of frequency-translation devices. The advantages of this system include:

- Improved absolute and relative group delay measurement accuracy of ±150 ps
- Lower measurement ripples for highly accurate S-parameter measurements
- Vector-calibrated performance (by characterizing and removing test system errors)

The basic Z2005A/H92 system consists of a network analyzer, customized hardware, computer with customized software, power meter, and synthesized source, as shown in Figure 1. The technique implemented in this system consists of two steps. The first step involves the creation of a mixer calibration standard using a vector network analyzer (VNA). The mixer calibration standard, fully characterized by HP, is provided with the system. The second step involves the use of this mixer calibration standard, along with a standard coaxial calibration kit, to calibrate the VNA-based test system. Once the significant error terms are characterized, a frequency translation device can be connected (in place of the calibration mixer), and its vector-error corrected response is measured.





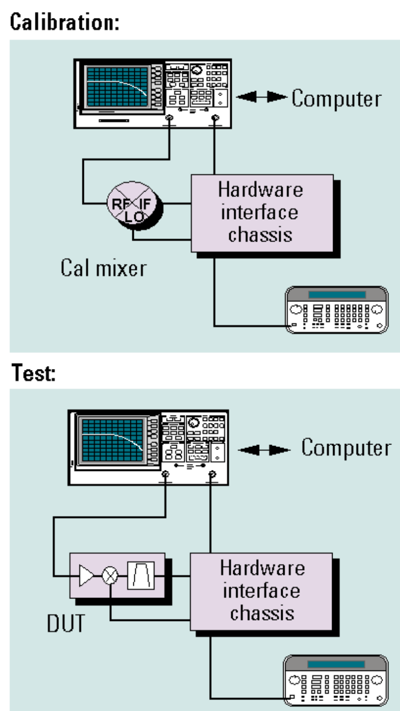


Figure 1: Basic System Configuration.

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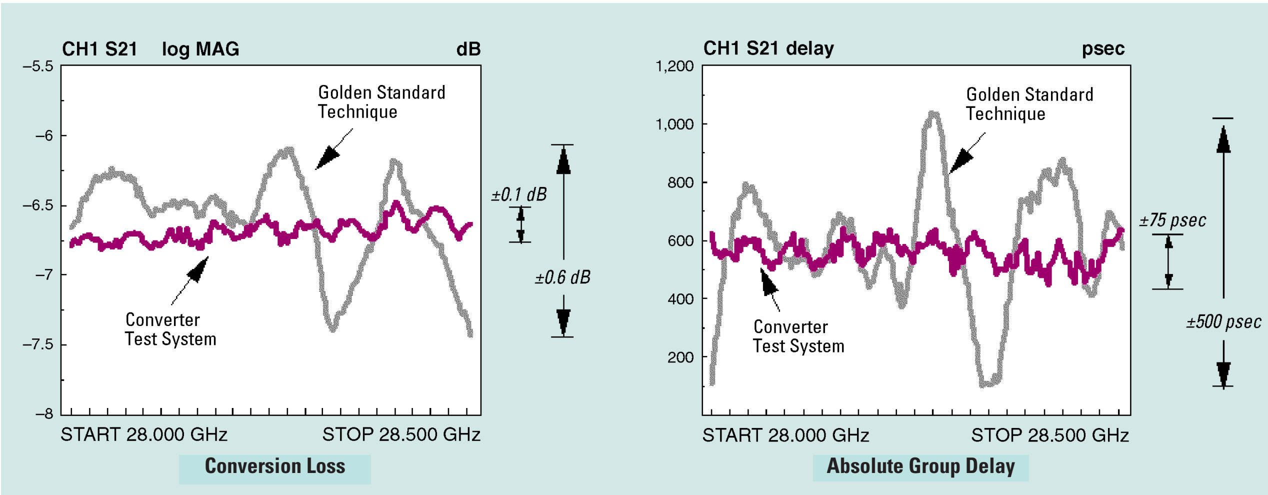


Figure 2. Measured Results.

The creation of a mixer calibration standard is achieved through an indirect measurement technique. There is no direct way to measure the absolute group delay characteristics of a mixer. Instead, by measuring three similar mixers in pairs, the simple mathematical technique for solving three equations with three unknowns can be applied. This approach has been used by Hewlett-Packard for many years when characterizing the phase noise of unknown oscillators. The technique can be used to extract the absolute response of each mixer, thus providing the response information needed (absolute group delay and conversion loss) when the mixer is used as a calibration standard. This mixer calibration standard is further characterized by direct measurements of its input and output match.

The calibration mixer, along with additional calibration standards, is used to correct for errors within the test system. A computer is used to store data files (of the calibration mixer and other components), extract error terms from the VNA, modify the error terms, and import the modified error terms back into the VNA for error-term calculations. After calibration, absolute group delay and S-parameter measurements can be made on the frequency translation device under test (DUT) with the added advantages of high accuracy, ease-of-use, and faster measurement throughput. Figure 2 compares the difference in measurement ripple between this technique and a golden standard substitution technique.[1]

Need more information?

This measurement technology is detailed in a new HP Application Note, 1287-7, *Improving Network Analyzer Measurements of Frequency-Translating Devices*. It is available on the World Wide Web **(http://www.tmo.hp.com/tmo/Notes/English/5966-3318E.html)** or by asking your HP sales office for HP literature number 5966-3318E. Your HP sales engineer can also provide more information about the HP Z2005A/H92 customized system and should contact Dennis Poulin at T-221-5053. ■

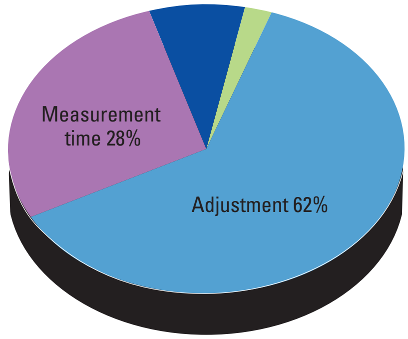
> “*Absolute group delay accuracy is specified at an impressive ±150 ps, whereas alternative techniques may have typical accuracy of a few ns.*”

1. In the golden standard technique, you perform a thorough response calibration with a reference mixer in place. Next, you enter the absolute group delay of the reference mixer via the electrical delay feature of the VNA. Finally, you connect your DUT and measure its response relative to that of the reference mixer. In this technique, you must know the absolute group delay of the reference mixer. This may be provided by the manufacturer, but is not a typical specification. Depending on the measurement technique used by the manufacturer, the uncertainty of their group delay measurement will add to the uncertainty of your measurement.

Your questions answered...

Increasing throughput

Q At my company we have set some challenging goals for reducing manufacturing costs by increasing the throughput of our production lines. How can I improve throughput in test processes that use network analyzers?



For the duplexer tuning example, measurement time is only about one-quarter of the overall process time.

A For network analyzer applications, many people focus on the sweep time of a network analyzer. It is important, however, to realize that sweep time is only one part of the test process. And optimizing it may not be the best way to improve throughput.

For example, consider a manual tuning process for a base station duplexer filter. This might include connecting the Tx and Ant ports to the analyzer, recalling an instrument state and calibration, adjusting screws to tune the filter, connecting the Ant and Rx ports, recalling a new instrument state and calibration, doing more adjustments, checking the Tx-Ant measurement and re-tuning if necessary, then verifying all measurements and disconnecting the filter. A single iteration through this process would have most of the time taken up by adjustments, with measurement time being about one-quarter of the total throughput time.

Mirin Lew, Product Manager, HP's Microwave Instruments Division

The next item in *Tips & Techniques* describes a new filter tuning method that could be used to reduce the adjustment time, which is the most time-consuming part of this test process.

To reduce measurement time, you might consider using swept-list mode. This feature (available in the HP 8753E, 8719D, 8720D, and 8722D) allows you to set up a customized sweep, and is especially helpful for testing filters. You can measure many data points in regions of interest, and only measure a few points or none at all in frequency spans where specifications are not critical. You can also set the power level and IF bandwidth independently for each segment of the sweep. This allows you to optimize dynamic range for measuring filter stop bands without slowing down the measurement in the pass band.

There are many other ways to improve sweep speed besides using swept-list mode. Application Note 1287-5 explains these methods in more detail. The application note also discusses the impact on throughput from other parts of a typical test process—such as instrument state recalls, use of limit lines or markers, data transfers to an external controller, device connection, and measurement accuracy. It provides suggestions for optimizing test time and improving throughput in many areas.

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> *“It is important to realize that optimizing sweep time may not be the best way to improve throughput.”*

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Tuning cavity resonator bandpass filters—faster

Q I use network analyzers to tune cavity resonator bandpass filters, and it takes even a skilled person quite a while to tune each filter. Is there a way to speed up this process?

A HP has developed an innovative resonator filter tuning technique that may significantly reduce your tuning time and allow tuning to be done by operators who have less training and experience. This new technique uses the time domain response instead of the traditional frequency domain view of the filter's reflection characteristics for tuning.

Some of the challenge in tuning resonator filters is in identifying which resonator needs to be tuned, and determining how to tune it to obtain the desired response. The concept behind the new technique is that the signal passing through a resonator filter experiences delay through each resonator. In time domain, this delay makes it possible to distinguish the effects of tuning each individual resonator for a specific response that results in a properly tuned frequency response.

Start by setting up the frequency domain measurement. The center frequency of the frequency sweep must be set to the desired center frequency of the bandpass filter. Choose the span to be three to five times the bandwidth of your filter. A full two-port calibration should be performed to properly set the reference planes for the S11 and S22 measurements and correct for the usual systematic errors.

After calibration, you can use interpolated error correction to look at measurements over more narrow frequency ranges. Now, measure S11 and turn on time domain (press [SYSTEM] [TRANSFORM MENU] [BANDPASS] [TRANSFORM ON] on an HP 8753 or 8720 family network analyzer).

Next, to determine where to set the start and stop limits in time domain, we need to consider the delay of the filter. A good estimate of the one-way delay through the filter can be obtained by measuring a properly tuned filter. Measure transmission (S21) in the frequency domain using the delay format, and look for the maximum delay within the pass band of the filter. A reflection signal (S11 or S22) would experience approximately two times that filter delay: once going out and once returning to the input port. For a filter with N resonators, the delay through any one resonator would be approximately the one-way delay divided by N.

If a properly tuned filter is not available, the delay can be estimated from the 3 dB bandwidth of the filter (BW). The delay is approximately $1/[(BW/2\pi) \times N]$. Since this approximation varies in accuracy for different types of filters, add about 20% to this value and use that as the estimated delay.

The recommended start limit is one resonator's delay on the negative side (time < 0). Remembering that an S11 measurement includes two times the actual delay, that makes the start = –1 x (delay/N) x 2. For the stop limit, we need to make sure we include enough time to see the signal reflected from all the resonators, so we recommend adding one resonator's delay to the delay through the full filter: stop = 2 x [(delay) + (delay)/N].

Figure 1 shows the time domain response of a properly tuned filter that has five resonators, with the corresponding S11 measurement in the frequency domain. Notice the almost periodic dips in the response. Beginning with the first dip near time=0, the next N dips represent the response of resonators 1 through N in the filter. You can see this in Figure 2, where we have deliberately mistuned the third resonator. The third dip is no longer at a minimum, but the dips from resonators 1 and 2 are still visible. Note that in the frequency domain response, it is much more difficult to see which resonator is not tuned. With some experimentation, you will find that tuning each dip for its minimum value results in a properly tuned filter in the frequency domain.

Using this information, you can now try adjusting a filter that has not been tuned. Start with the resonator closest to port 1, and tune it until you see the first dip showing up near time=0. Change your adjustment slowly because the dip in the time domain is very sensitive to tuning, and it is easy to tune right past it. Next, tune resonator 2 until its dip reaches a minimum. There will probably be some interaction between the resonators so that the dip from resonator 1 is no longer at a minimum, so go back to resonator 1 and tune it again. Go back to resonator 2 and minimize that dip, then go on to resonator 3, and so on.

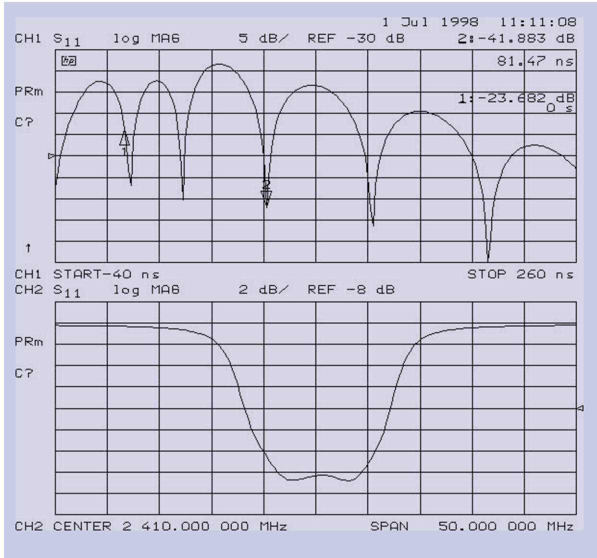

Figure 1. Response of tuned filter.

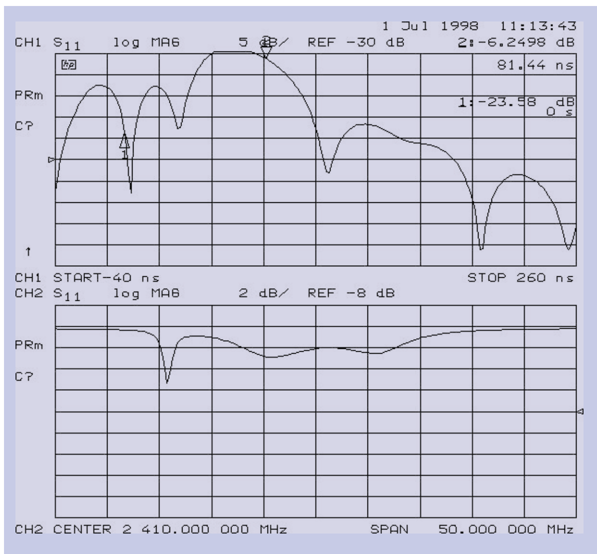

Figure 2. Filter with resonator 3 mistuned.

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Be sure to go back and re-tune the previous resonator each time. Note that since energy gets lost as it goes through the filter, it may become too difficult to properly tune the later resonators. It is a good idea to tune half of the resonators looking at S11, and then switch to measuring S22 to tune the remaining resonators. When you change to S22, you need to start with the resonator closest to port 2 (which will now be the first resonator in the time domain response), and repeat the tuning process, working backward through the resonators from port 2 toward port 1. When all the resonator dips in time domain have been minimized, turn time domain off to return to the frequency domain measurement. The filter should now be properly tuned.

“The ability to identify and optimally tune each resonator allows tuning of complex filters to be done more quickly and accurately.”

One difficulty with this technique is knowing where the dips for each resonator should appear in the time domain response, especially when working with an unfamiliar filter. This problem can easily be solved by starting with a properly tuned filter and storing its time domain response as a memory trace to create a template. The memory trace can be displayed along with the data trace while tuning, so the operator can see where the dips should appear.

This tuning method works well with all-pole filters with simple coupling, for instance, where every resonator is coupled to the adjacent resonators. There are other filters with more complex characteristics, such as cross-coupled filters, and filters where the coupling between resonators can be tuned as well as the resonators themselves. For these filters, simply minimizing resonator dips in the time domain response may not be sufficient.

More investigation is being done to refine this technique for these types of filters. You may want to try creating a template to define the optimal response for operators to use, as described in the previous paragraph.

Since this technique is fairly simple, only moderate training is needed for operators. The ability to identify and optimally tune each resonator allows tuning of complex filters to be done more quickly and accurately.

Note that although this technique can be used on any network analyzer with bandpass time domain transform, it is not practical unless the analyzer is fast enough to allow close to real-time tuning in time domain. The HP 8753E, 8719D, 8720D, and 8722D with firmware revisions higher than 7.0 have a new faster CPU board that can be used for this type of tuning. HP 8753D analyzers and older 8720 family analyzers can be upgraded by ordering Option 000 with the appropriate upgrade kit of HP 8753DU, 8719DU, 8720DU, or 8722DU. ■

Now up to seven times faster!

Chad Gillease, Product Manager, HP's Microwave Instruments Division

Good news. The HP 8719D, 8720D and 8722D VNAs now include: a new 68040 CPU, two wider IF filter bandwidths (3.7 kHz and 6 kHz), new faster DSP hardware, and code enhancements which provide exceptional sweep speed, error correction, register recall and data-transfer rates. Other productivity enhancements include:

Four-parameter display

Measure and display all four S-parameters simultaneously (available October 1998). This feature can significantly reduce measurement throughput time for tuning/testing duplexers, isolators and other devices. Display reflection and transmission parameters with magnitude, phase, group delay, Smith chart, polar, SWR, or time-domain formats. View results in overlay or split-screen format on an LCD color display with one, two, or four graticules. Quickly record or print all four S-parameters for data archiving.

Swept-list mode

Speed up your testing by measuring at only selected frequencies. You can specify up to 30 arbitrary CW frequencies or frequency sweep segments at which to test your device. You may independently set test-port power levels, number of data points and IF bandwidth for each segment. Reduce test time and increase measurement throughput by optimizing each segment to your specific test requirements.

Fast data transfer to your CAE program

The Touchstone©-compatible (S2P) format provides fast S-parameters data transfers for new design and simulation applications.

Faster performance for existing features

• Automate measurements quickly and easily with keystroke recording.
• Recall measurement states with the push of a button.
• Save time and avoid recalibration when changing frequencies by using the interpolative error-correction mode.
• Locate and resolve mismatches in your test device, fixture or cable using time-domain analysis.

New features improve your measurements

• Save more complex calibration data and instrument-states with increased nonvolatile memory.
• Use the built-in disk drive to quickly and easily upgrade the flash memory-based firmware.
• Accurately measure non-insertable devices with adapter-removal calibration.

To upgrade your existing HP 8720D family analyzer...

Option 000 for the HP 8719DU, 8720DU, and 8722DU analyzers provides all the new performance and features for the HP 8720D family of vector network analyzers. For more information, ask your HP sales engineer or visit us on the World Wide Web (http://www.hp.com/go/8720). ■

Calibrate electronically with HP's new ECal modules

Want to speed up your calibrations? Try HP's new Electronic Calibration (ECal) modules for your HP 8510, 8720 and 8753 series vector network analyzers. ECal is ideal for the manufacturing environment. A full two-port calibration can be accomplished with a single connection to the ECal module, using minimal operator intervention.

New microwave and RF ECal modules

Sal Caruso, Product Manager, HP's Santa Rosa Systems Division

The new HP 85090 series RF ECal modules provide calibration for your HP 8753C/D/E network analyzers. Calibration performance is specified from 300 KHz to 6 GHz and typical from 30 KHz to 300 KHz.

Operating on the 1 GHz to 18 GHz or 26.5 GHz frequency range, the improved HP 85060 series microwave ECal modules provide calibration for the HP 8510B (firmware revision 6), 8510C, 8719C/D, 8720C/D and 8722C/D. Order Option 001 to add an RF module (30 kHz to 6 GHz) for the lower frequency range of your network analyzer.

Both the HP 85060 and 85090 ECal modules are available in 7 mm, Type-N, and 3.5 mm. Standard Type-N and 3.5 mm ECal modules are equipped with male and female connectors and options 00M and 00F are available with male-to-male or female-to-female connectors.

Also new from Hewlett-Packard, the HP 85097A PC interface—with control software—allows you to control the ECal module with a PC during the calibration process.

Availability and pricing

The HP 85090/85060 series ECal modules and HP 85097A PC interface are available now. Prices begin at $3,000 (U.S.) for the HP 85090 series of RF modules, and $6,430 for the HP 85060 series of microwave modules. The PC interface (HP 85097A) is priced at $1,400. Delivery is estimated at four weeks for the HP 85090 series, and ten weeks for the 85060 series. ■

> *"With ECal, a full two-port calibration can be accomplished with a single connection to the ECal module, using minimal operator intervention."*

New, lower pricing on HP 8510 instruments and systems

This is your opportunity to save 10 to 25%! HP has reduced the prices on more than 20 products in the HP 8510 vector network-analyzer family.

Modular solutions

For complete measurement flexibility, our high-performance HP 8510 family is modular. A typical system is assembled with a receiver, a test set that covers your measurement frequency, and a microwave source. Measurements can be performed over a wide range of microwave and millimeter frequencies. Accommodate your changing measurement needs by changing or upgrading components of the system.

Complete rack system

The HP 85107B, on the other hand, is a complete factory-integrated test system mounted in a rack. It includes a calibration kit and test port cables, on-site installation, one day of engineering consulting, and one full year of on-site service. Frequency range is 45 MHz to 50 GHz.

Upgrades reduced, too

If you have an existing HP 8510 system, now is the time to upgrade at reduced prices. For instance, U.S. customers with 20 GHz or 26.5 GHz systems may now upgrade to 50 GHz systems for $72,035 (a 23% reduction). Or if you have an HP 8510A or 8510B analyzer, you may now upgrade to the higher performance HP 8510C for just $16,250 or $12,463, respectively. You'll save 23%.

Look on the Web for more product savings

A complete list of products included in this price reduction is found on the World Wide Web at: **http://www.hp.com/go/8510**. Or as always, you may call your local HP sales office. ■

Price Reductions (in U.S. dollars)

Product	Current U.S. Price	New U.S. Price	% Reduction
HP 8510C vector network analyzer	$ 41,515.	$ 31,800.	23%
HP 8517B 50 GHz S-parameter test set	$ 47,530.	$ 35,035.	25%
HP 83651B 50 GHz source	$ 47,075.	$ 37,000.	21%
HP 85107B 50 GHz system	$150,500.	$120,000.	20%

Millimeter Upgrade Promotion

If you currently own an HP 85106C/D or HP 85109C and want to achieve single sweep, on-wafer measurements up to 110 GHz, you can trade in your used V/W8510As and HP 85105As for credit towards the purchase of an HP 8510XF or HP 8510XF upgrade. This promotion expires March 31, 1999.

Find us on the Web, beginning Spring 1999!

HEWLETT PACKARD
Expanding Possibilities

Dear reader:
Good news! Beginning with our March 1999 issue of *HP 8510/8720 News*, you'll be able to find us on the World Wide Web. This means easy access for you, and quicker delivery of those important product articles. You may even notice our new look— a new design, and lots of color!

When you're at the newsletter web site, you'll also be able to "link" to:

- Previous issues of the 8510/8720 newsletter
- Free firmware upgrades
- Training news

…and much, much more. Come visit us on the "WEB" and you'll see!

We'll send you an e-mail twice a year, letting you know the new issue is available. You will find the newsletter at:

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