HP 8510 8720 NEWS

November 1990
Volume 1 -Number 3

The newsletter for users of HP 8510 and 8720 network analyzers

The importance of uncorrected test set performance

The accuracy of measurements made with microwave network analyzers such as the HP 8510 and 8720 has been continually improved over the years. Advancements in error-correction techniques such as Short-Open-Load-Thru (SOLT) or Thru-Reflect-Line (TRL) have been useful in removing with greater accuracy the stable and repeatable errors from measurements. Additionally, new modeling, design and manufacturing techniques for calibration standards have contributed substantially to the improvement in measurement accuracy of microwave network analyzers. However, an area of improvement that is often overlooked is the performance and stability of the microwave hardware in the network analyzer.

Today, built-in error-correction techniques are available in microwave network analyzers as standard features. And although error-correction can remove most of the effects of imperfect hardware, the raw (or uncorrected) performance of the hardware is still important. This is especially true at the higher microwave frequencies where small changes in temperature or other variations can cause significant errors in the accuracy of a measurement.

In order for the error correction to be thoroughly effective, the error terms must be systematic and stationary and must behave in a linear fashion. If these conditions are true, the calibration will remain valid and will not have to be repeated. Reality dictates, though, that random errors such as noise, distortion, non-linearity, drift, switch repeatability, connector repeatability, and cable stability cannot be removed from the final measurement. Therefore, a calibration will drift as a function of time or temperature and will have to be repeated periodically.

Residual vs. raw test set performance

Performance specifications after error correction can be found in network analyzer technical data sheets. Corrected (or residual) directivity is on the order of 35 to 60 dB, and corrected source match and load match is on the order of 30 to 60 dB. Performance specifications before error correction are a little more difficult to come by. Typically, raw directivity is on the order of 7 to 30 dB, and raw source match and load match is on the order of 6 to 25 dB.

continued on next page

Also in this issue:

HEWLETT PACKARD

A summary of HP 8510 test set performance is shown below. The most recent test set addition is the HP 8517A 45 MHz to 50 GHz coaxial S-parameter test set. The design goal of this test set was to achieve good raw performance to 50 GHz. And, although the performance improvements are not apparent from the residual numbers, they contribute directly to the measurement stability that can now be achieved to 50 GHz.

	HP 8515A	HP 8516A	HP 8517A
Frequency	26.5 GHz	40 GHz	50 GHz
Raw directivity	27 dB	7 dB	20 dB
Raw port match	14 dB	6.5 dB	10 dB

Measurement stability

The measurement stability of a one-port measurement system is affected by changes in the raw directivity, match, and tracking terms as well as by the absolute value of the raw tracking term and the actual return loss of the device under test.

Equation 1

$$A \quad I \frac{AD}{1+T}, = \frac{I- \bullet AT}{1+T} + - + \Gamma^2 \bullet \Delta M$$

Where

$\Delta\Gamma_c$	=	change in calculated return loss
T	=	raw reflection tracking
D	=	raw directivity
M	=	raw source match
1-	=	actual DLJT return loss

Designing higher quality microwave network analyzer hardware to improve the raw performance is one way to increase measurement stability. The components of the network analyzer test set such as the directional couplers, bias tees and step attenuators must be stable and exhibit good raw performance. The inherent performance of these components will have an effect on the overall stability of the system. However, as the frequency coverage of microwave network analyzers is extended higher and higher, this design goal becomes much more difficult to achieve.

Raw directivity

The overall system directivity of a network analyzer system is largely a function of the quality of the signal separation devices (i.e. directional couplers). Figure 1 shows that as the raw directivity becomes a larger error D2, small changes in the system (due to instabilities) will have a proportionately larger effect on the measurement.

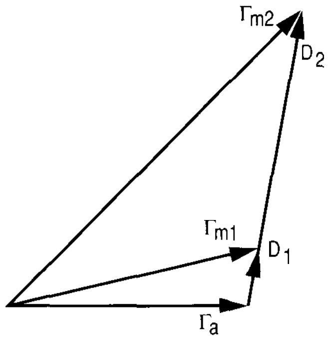


Figure 1.
Better raw directivity reduces the error vector and measurement instability.

From Equation 1, it is evident that if there is significant loss after the directional device (i.e. cables, adapters, fixtures, or probers), the sensitivity of the calculated return loss to changes in raw directivity is increased by 1 /loss. Thus, at higher frequencies, as losses become greater, the need for stable raw directivity becomes even more important.

Good raw directivity means that the network analyzer system will be less susceptible to changes in the system caused by drift. A measurement system that is more stable requires fewer recalibrations. A comparison of measurement stability of two different systems shows that improved raw directivity affects the frequency with which calibrations must be repeated (see figures 2 and 3).

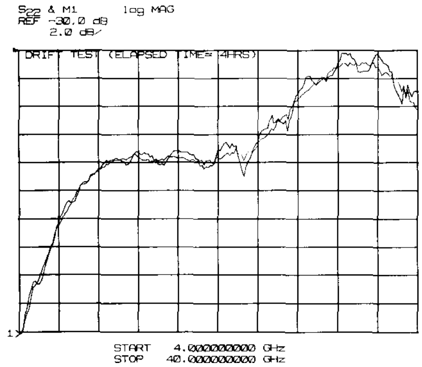


Figure 2.
Load measurement stability with 11 dB of raw directivity over a 4-hour time span.

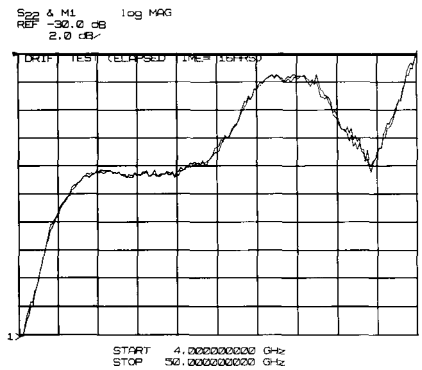


Figure 3.
Load measurement stability with 20 dB of raw directivity over a 16-hour time span.

Raw port match

The system port match is determined by the match of the components that make up the network analyzer test set (i.e. directional couplers, bias tees, step attenuators, power splitters, and switches). Raw port match affects the overall accuracy of the measurement as well as the behavior of match-sensitive active devices.

The absolute value of the raw port match also has an effect on the corrected transmission tracking error term.

continued on next page

Equation 2

$Tc = T \bullet (1 - M_s \bullet \mu_l - M_l \bullet \mu_s)$

Where Tc = calculated transmission tracking
T = actual transmission tracking
Ms = raw source match
Ml = raw load match
μ_s = residual source match
μ_l = residual load match

Equation 2 shows that the error in the transmission tracking term is

$(M_s \bullet \mu_l - M_l \bullet \mu_s)$.

This error can be reduced by either improving the residual port match with better standards or error-correction techniques or by improving the raw port match terms.

Frequency response

The frequency response (or tracking) is also an important raw test set characteristic to consider. Ideally, a test set should exhibit a perfectly flat frequency response. In reality, test sets will have a roll-off due to increased losses at the low and high ends of their frequency range. The frequency response affects the overall power flatness that can be achieved at the test port as well as the achievable dynamic range of the measurement system. The goal is to design high quality, low loss components so that a relatively flat frequency response is maintained at the network analyzer test port.

Summary

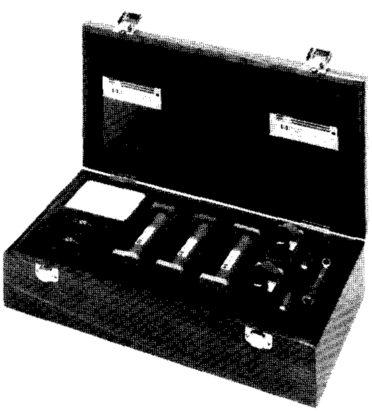
Good raw performance of the network analyzer microwave hardware is important because measurements are less sensitive to environmental effects and fewer recalibrations are required. If the network analyzer components do not have good raw performance, the stability of the system may be degraded. Furthermore, the inherent performance of any network analyzer system can be further degraded with the addition of cables, fixtures, probers, etc. that are commonly placed between the network analyzer and the device under test.

In summary, although error correction can correct for imperfect hardware, the ultimate quality of the measurement is dependent upon the combination of the quality of the error-correction technique, calibration standards, and raw performance of the microwave hardware.

New Products

New waveguide calibration kit for X/P/K-bands

Hewlett-Packard now offers three new calibration kits for measurements from 8.2 to 12.4 GHz, 12.4 to 18 GHz, and 18 to 26.5 GHz in rectangular waveguide.



These HP 11644A-series calibration kits are compatible with the HP 8510 and HP 8720 network analyzers. When used with the HP 8510, the TRL calibration technique (Thru-Reflect-Line) may be used to achieve an impressive 50 dB of directivity and match. The kits also support the traditional waveguide calibration technique (Short-Offset Short-Load-Thru).

Each kit contains a flush short, plus a 1/4-wavelength shim to "offset" the short or to use as a "line" standard with TRL. Fixed terminations serve as loads (42-dB return loss typical) or isolation standards. Two low-SWR adapters are included to convert from coax to waveguide interfaces.

All waveguide components in the kit feature HP precision flanges that mate with standard **flanges,** yet offer improved match and connection repeatability. For compatibility, the flanges also include two additional holes for precision alignment dowels, as recommended by the NPL (National Physical Laboratory).

	HP X11644A	HP P11644A	HP K11644A
Band Designations	X	P (K_u)	K (K_a)
Nominal Frequency Range (GHz) (TE_{10} Mode)	8.2 to 12.4	12.4 to 18.0	18.0 to 26.5
Waveguide Designations			
EIA (Electronic Industries Association)	WR-90	WR-62	WR-42
IEC (International Electrotechnical Commission)	R-100	R-140	R-220
British Designation	WG-16	WG-18	WG-20

For more information on these kits, see the HP X/P/K11644A technical data sheet (HP literature number 5952-3529).

continued on next page

Next-generation HP 8510C delivers RF performance to 50 GHz

The HP 8510C is the next significant step in a continuing 25-year evolution of high performance network analyzers from HP. It delivers breakthrough RF performance to 50 GHz, in 2.4 mm coax, with advancements in system measurement speed and usability.

The HP 8510C and its companion 50 GHz test set (HP 8517A) advance RF performance and dynamic range limits beyond what was available previously to 40 GHz.

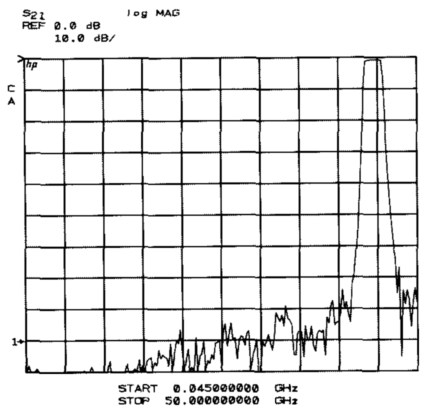


Figure 1. The new 50 GHz test set has excellent dynamic range.

"No-compromise" RF performance to 50 GHz

The HP 8510C and 8517A combination eliminates the trade-off that exists between RF performance and frequency range when choosing among current 26.5 GHz and 40 GHz systems. The uncorrected (raw) RF performance delivered by the HP 8517A is exceptional, with better than 20 dB directivity and 10 dB port match at 50 GHz. Excellent raw RF performance results in significant benefits, including higher overall accuracy after calibration and longer lasting calibrations (see this issue's feature article,"The Importance of Uncorrected Test Set Performance"). Because of much lower path losses in the test set, the 50 GHz system provides 10 dB more dynamic range at 40 GHz than previously available. Even at 50 GHz the system meets, or exceeds, previous 40 GHz dynamic range levels (see Figure 1). The dynamic range at the low end of the frequency range has also been improved.

Faster measurement updates with higher frequency accuracy

The analog "ramp" sweep mode of the HP 8510 is still unmatched for overall measurement speed. With the HP 8360 synthesized sweeper as source, the swept frequency accuracy of ramp mode improves by an order of magnitude (see Figure 2). Now more applications can benefit from the rapid update rates made possible with ramp sweep.

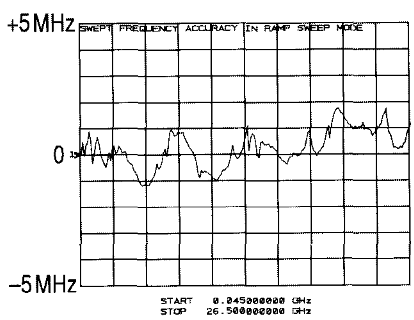


Figure 2. Ramp sweep mode is both fast and accurate (± 0.1% of span).

The best frequency accuracy is still accomplished using the "step" sweep mode where the frequency of each measurement point is synthesized to 1 Hz resolution. Measurement speed for step sweep is also improved with the HP 8510C "quick-step" feature. The source is continuously tuned from one synthesized frequency to the next. This eliminates the time required to re-phaselock the receiver at each point and reduces frequency switching time to under 10 msec. This is six times faster than previously achievable with the HP 8340-series synthesized sweeper.

Corrected power flatness at the test port

The HP 8510C is the first microwave vector network analyzer capable of delivering flat output power vs frequency at its measurement port. With a one-time connection of an HP 437B power meter to the measurement port, a correction table of loss vs. frequency is computed and used by the source to provide constant test port power at each frequency (see Figure 3). With this capability, testing of level-sensitive devices is less frustrating, and absolute power can now be measured directly with the network analyzer.

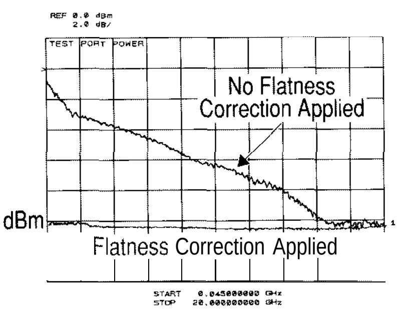


Figure 3. Maintain constant input power to active components with test port power flatness correction feature.

continued on next page

Enhanced usability with full color display

The large (7.5-inch/19 cm), color CRT can display all four S-parameters of a test device simultaneously on a single, full-size graticule. The active marker for each S-parameter is also displayed simultaneously, allowing the user to instantly see complete results at critical frequencies. Alternatively, all five marker readouts for a single S-parameter may be viewed at the same time. With 16 customizable colors to choose from, it's easy to differentiate between multiple measurement traces and other display features. The built-in 3 1/2-inch disk drive performs all the storage functions of the previous HP 8510B tape drive. Both LIF (for HP 9000-series computers), as well as the popular MS-DOS ® disk file formats, are supported.

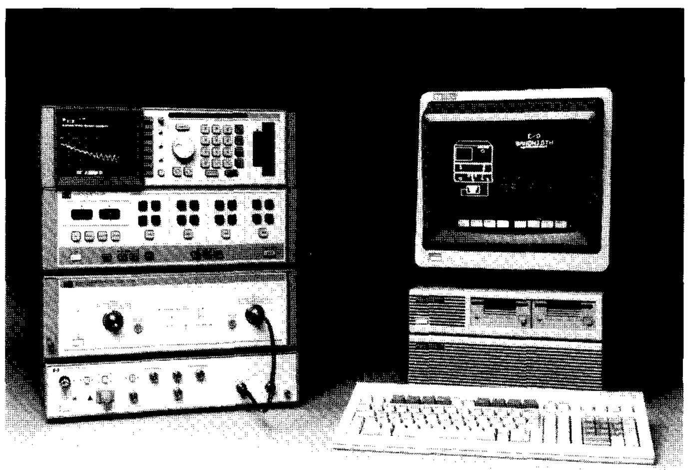
Hardcopy outputs can be directly produced on a plotter or graphics printer, including the popular HP LaserJet printers. Measurement results can also be printed in a customizable tabular format. Serial output ports (RS-232-C) have been added, providing buffers that keep the front panel active during plotting or printing operations.

Upgrade packages are available

Any HP 8510A or 8510B network analyzer can be upgraded to the full capability of the HP 851OC. The HP 85103C (for 8510A's) and the 85103D (for 8510B's) contain all the new hardware and firmware needed to convert on existing network analyzer into an HP 851OC. The new 50 GHz test set and source may be added to either an HP 8510B (with Rev 6.0 firmware), or an upgraded HP 8510C. All existing test sets and sources are compatible with the HP 8510C. For a limited time, the HP 85103C/D upgrade packages are offered at very attractive prices (20% to 30% below the full list price of the kits).

For more detailed information on the new HP 851OC and 50 GHz products, consult the HP 851OC brochure and technical data sheet (HP literature numbers 5952-3187 and 5952-3188).

Upgrade HP 8510 and 8720 systems to lightwave



Expand the capability of your existing HP 8510 or 8720 network analyzer to make calibrated 20 GHz transmission and reflection measurements of lightwave devices by adding the new HP 83420A Lightwave Test Set. The HP 83420A lets your HP microwave network analyzer test the base band magnitude and phase characteristics of lasers, LED's (E/O), photodiodes (O/E), optical modulators, optical fiber (O/O) and other optical assemblies. Now you can view the same type of frequency and time (distance) domain formats in microwave measurements and lightwave measurements.

These capabilities are provided by the HP 83420A's internal 1300 nm Fabry-Perot laser (or optional 1300 or 1550 nm distributed feedback laser), a directional lightwave coupler, and an amplified lightwave receiver. Hardware and computer software for interfacing with the HP 8510 HP 8720/H80 or HP 8719/H80 microwave test systems are also provided. Measurement automation and calibration is achieved with the test set control program running on an HP 9000 Series 200 or 300 computer (the HP 9826 is not included), or on a PC.

Product Note 8510-15 (HP literature number 5952-3524) provides full details on how to make lightwave component measurements with the HP 8510 or 8720 network analyzers.

Tips & Techniques

Q Why does the HI' 87208 plot slower than the HP 8720A?

A A built-in plotter buffer was added to the HP 8720B feature set. It allows the network analyzer to continue sweeping and make the next measurement, while also controlling the plotter (or printer) in its "spare time." You can go ahead with your measurements while the plotter works.

If getting the plot done is really the top priority, you can easily disable this feature by putting the network analyzer in HOLD mode. (Press [MENU] in the STIMULUS group, then [TRIGGER MENU], then [HOLD].) This stops the sweep, and allows the HP 8720B to drive the plotter as fast as it can go. When the plot is done, select [CONTINUOUS] to resume sweeping.

Q What is CITIfile? I'm interested in learning more about its use.

A The Common Instrumentation Transfer and Interchange file format (CITIfile) is a standard ASCII disk file format for exchanging data and setup information between instruments, computers, and people. The HP 8510 and HP 8720 network analyzers use the CITIfile format when you store the memory, cal set, data, or delay table type files to disk (SAVE USING ASCII).

CITIfile defines the contents of ASCII format text files. Each line consists of ASCII characters terminated by a cr/lf. These files may be created, examined, and edited using many applications, including HP BASIC and the HP Microwave Design System (MDS). Likewise, files created using the CITIfile format by HP BASIC or HP MDS may be read by the HP 8510.

This example shows a CITIfile disk file created by storing a DATA: DATA (corrected data) type disk file from the HP 8510.

```
CITIFILE A.01.00
#NA VERSION HP8510B.04.00
NAME DATA
VAR FREQ MAG 201
DATA S [1,1] RI
SEC-LIST-BEGIN
SEG 1000000000 4000000000 201
SEG_LIST_END
BEGIN
0.86303E-1,-8.98651E-1
8.97491E-1,3.06915E-1
-4.96887E-1,7.87323E-1
 . Dependent Variable
 Data List

-5.65338E-1,-7.05291E-1
8.94287E-1,-4.25537E-1
1.77551E-1,8.96606E-1
END
```

The HP 8510 measured 201 data points from 1 GHz to 4 GHz. This file consists of the title line, file name/type, optional definitions for the measurement environment, declarations and data lists for the independent variable (usually frequency), and declarations and data lists for the dependent variable (the measured data). The list for the dependent variable in this example is shortened, but an actual file listing would contain 201 data lines.

Perhaps the best way to familiarize yourself with CITIfile is to actually read a file. Following is a simple BASIC program to read and print the contents of a CITIfile.

```
10 ALLOCATE Filename$ [30],
     Current_line$[256],Response$ [30]
20 PRINTER IS 1
30 LINPUT "Name of File to
     Read?",Filename$
40 ASSIGN @Discfile to Filename$
50 ON END @Discfile GOT0
     End-of-file
60 PRINT "* DISK FILE NAME:
     '"&Filename$&"' *"
70 REPEAT
80 ENTER @Discfile;Current_line$
90 PRINT Current-line$
100 UNTIL 0=1
110 End-of-file:!
120 PRINT "*** END OF FILE ***"
130 END
```

Q Why does my HP 8720 seem to sweep faster when I change the frequency sweep span?

A The time needed to complete a sweep (not including band changes or retrace) depends on the frequency span, as well as number of points, IF bandwidth, and other factors. The HP 8719 and 8720 have a [SWEEP TIME AUTO] mode, which always uses the fastest possible sweep rate.

Some situations require a sweep time longer than this minimum value to avoid measurement errors (i.e. when using long test port cables or when measuring a device with a large electrical delay). In these cases, choose [SWEEP TIME MANUAL] in the "STIMULUS menu and enter a long sweep time. Then, gradually reduce sweep time until you detect a significant change in the measurement.

If you have a network analyzer measurement tip or technique that you would like to contribute, please send it to the address shown on the back cover.

For Your Files

HP 8719 and 8720 updates and upgrades

Firmware updates are periodically made to the HP 8719A and 8720 network analyzers to add new features, enhance usability, or correct anomolies. The table below describes the key changes in each revision (as compared to the preceding revision), starting with the most recent.

To determine the HP 8719 or 8720 firmware revision you have now, turn on the network analyzer and press: [SYSTEM] [SERVICE MENU1 [FIRMWARE REVISION]. The first line of text on the display will resemble "HP8720B.01 .01".

The following firmware upgrade kits will bring an instrument up to the current revision. The kits contain the latest firmware available, and include a service note telling you how to install the new ROMs in sockets. Instrument states saved to disk from one revision can be recalled by any later revision.

Network Analyzer Model	HP Part Number
HP 8720A	08720-60020
HP 8719A	08719-60003
HP 8720B	08720-60009

Upgrading from 13.5 to 20 GHz

An HP 8719A can be upgraded to an 87208, raising its maximum frequency from 13.5 GHz to 20 GHz with the HP 86382A upgrade kit. The IO-digit serial number will be required. On-site installation by HP is included (where available).

Retrofitting time domain or 1 Hz frequency resolution

Time domain capability (option 010) can be added with the HP 86380A retrofit kit. With the HP 86381A retrofit kit, the frequency resolution of the synthesized source can be improved from 100 kHz to 1 Hz (option 001). Both kits are compatible with any HP 8719A, 8720A, or 8720B. The lo-digit serial number of the network analyzer is required. The kits include complete instructions for installing these options yourself (or if you prefer, HP will perform the installation).

HP 8719/8720 Firmware Revision History

HP8720A.02.03 or HP8719A.01.02 or HP8720B.01.02

- Allows system a ZO of up to 1000 ohms.
- Allows optical/lightwave dB mode (half-normal scale).
- Corrects STORE/LOAD from ASCII disk with dual uncoupled display.
- Corrects false failures in Operator's Check.
- Corrects scaling factor when plotting via OUTPPLOT command.
- START/STOP is correctly recalled in changing from CW to LIN.
- Corrects sliding load and coax/waveguide selections when saving USER KIT.

HP8720A.02.00 or HP8719A.01.01 or HP8720B.01.01

- Adds 4/8 marker values all on screen at same time.*
- Adds FORM5 floating-point reversed-byte I/O for MS-DOS PCs."
- Adds CITIfile ASCII disk format.*
- Adds waveguide delay and port extensions (dispersion).
- Adds duplicate SET SYSTEM ZO key to MODIFY CAL KIT menu.
- Improves sliding load cals for loads with >48 dB return loss.
- Eliminates FATAL ERROR when PLOT follows STORE to disk.

HP8719A.01.00 or HP8720B.01.00
(original release)

HP8720A.01.02

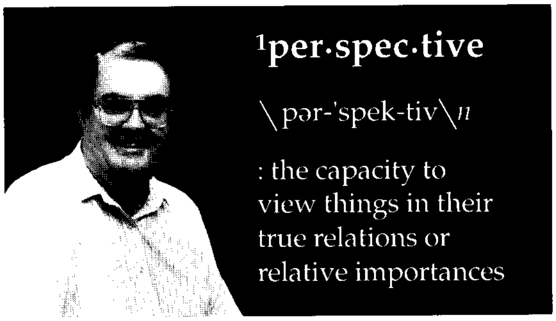
- Allows plotting of active entry value.
- Compatibility with Option 003 extended dynamic range.
- Changes OPERATING PARAMETERS to display Marker page first.
- Allows port extensions in log or list modes.
- Allows options to be retrofitted independent of existing options.
- Corrects 801-point transfers using INPUDATA in FORM2.

HP8720A.01.01

- Improves time domain low-pass and gating operation.
- Corrects model for type-N cal kit standards.
- Corrects false POWER SUPPLY SHUTDOWN failure at power-up.

HP8720A.01.00
(original release)

* Added to HP8720A.02.00 only; were already in HP8719A.01.00 and HP8720B.01.00.



With the introduction of the HP 8410A 12.4 GHz network analyzer system in 1966, a new era of broadband network analysis was born. The performance of this system relied completely on the raw (uncorrected) characteristics of the microwave components in the network analyzer test set. With the addition of a computer and error-correction software, the HP 8540 automatic network analyzer system was created. Error correction depended on knowing the exact value of the standards to reduce the negative effects of the imperfections of the hardware.

In 1984, the HP 8510A network analyzer revolutionized the way microwave engineers made measurements. It provided dramatic improvements in signal processing and detection hardware, and introduced built-in error correction. At the same time, broadband coaxial frequency coverage was increased to 26.5 GHz by incorporating high-quality microwave components into the test set, setting a new level for high performance.

Now, after years of extending the frequency coverage of hardware, improving the performance of calibration standards, and developing more powerful calibration algorithms, the key to improving the performance of modern network analyzers has come back to the inherent quality of the microwave components in the test set. Error correction can improve the measurement results obtained with marginal hardware, but with good hardware, error correction can produce excellent results.

The new 50 GHz system from HP was designed with the goal of creating the highest quality 50 GHz components with good raw performance. As described in the feature article of this issue, these improvements translate to more convenience for the user with simpler, more accurate and more stable measurements.

Doug Rytting

Doug Rytting
HP 8510 R&D Section Manager

Calendar of Events

Network Analyzer Users Groups
(Contact *sales office for dates)*

		North-East Chapter HP Burlington Sales Office	Burlington, Massachusetts
		North-West Chapter HP Bellevue Sales Office	Bellevue, Washington
		San Diego Chapter HP San Diego Sales Office	San Diego, California

Industry Trade Shows (also featuring HP 8510 and 8720 products and applications)

December	11-12	15th International Conference on Infared and mm-Waves Grosvenor Resort Hotel	Orlando, Florida
January	22-24	Hyper Palais des Congres	Paris, France
February	18-22	Optical Fiber Conference San Diego Convention Center	San Diego, California

Hewlett-Packard Company
c/o HP 8510/8720 News 4US-G
1400 Fountaingrove Parkway
Santa Rosa, CA 95403-1799
U.S.A.
FAX (707) 577-4527

Printed in U.S.A. 11/90
5091-0487E