HP 8753B

Simplify Your Amplifier and Mixer Testing

New Network Analyzer Has Nonlinear Measurement Capability.

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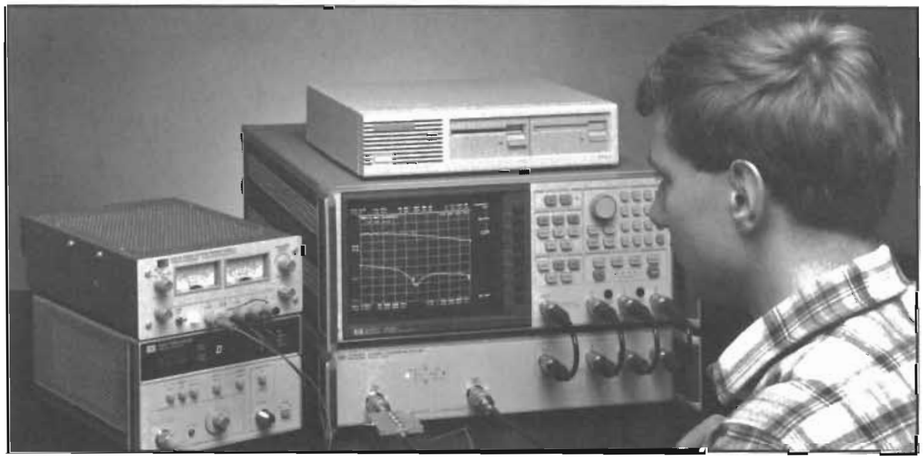
When measuring a device's linear and nonlinear characteristics, multiple test configurations are typically required. Network analyzers have traditionally been used to measure the linear reflection and transmission characteristics of RF components, such as filters and cables, by applying a known swept signal and then measuring the magnitude and phase of the transmitted and reflected signals. Active devices such as amplifiers and mixers, however, require both linear and nonlinear characterization. Each device must be moved between one test set-up to measure impedance, amplifier gain and mixer conversion loss and another set-up to measure harmonics and intermodulation distortion. The latest RF network analyzer from Hewlett-Packard Co., the HP 8753B, dramatically simplifies and speeds these tests. The ability to measure amplifier harmonics and mixer conversion loss is added to the contributions of its predecessor, the HP 8753A. In addition, the HP 8753B offers other new features designed to aid manufacturing test applications and provides frequency coverage from 300 kHz to 6 GHz.



The HP 8753B offers new features for nonlinear measurements and direct control of external instruments.

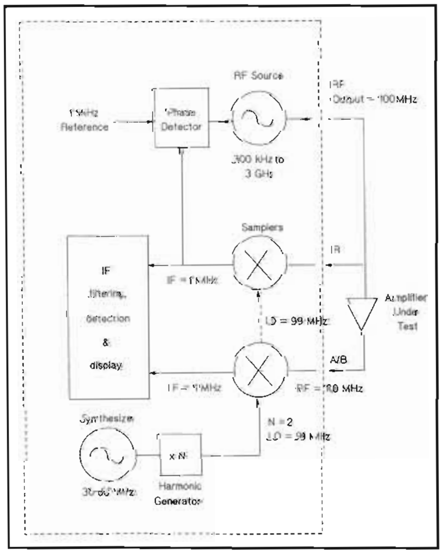


Figure 1a. Functional diagram for linear measurements.

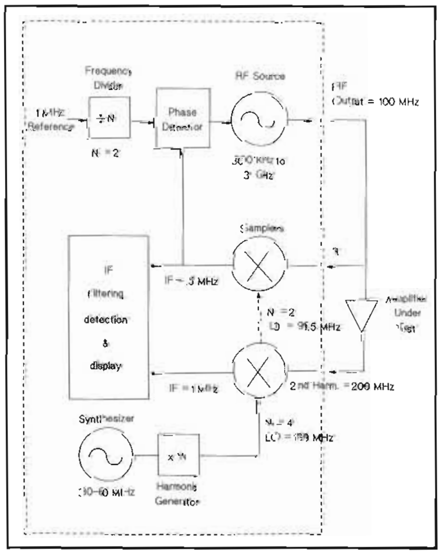


Figure 1b. Functional diagram for 2nd harmonic measurement.

A device's behavior is linear when a sine wave input produces a sine wave output at the same frequency with only an amplitude and phase change. Examples of linear devices are filters and cables. The output of a nonlinear device is dependent on the power level of the input signal and is usually composed of multiple signal components at harmonically-related frequencies. Examples of such devices are saturated amplifiers and mixers.

Figure 1a contains a block diagram which illustrates how the HP 8753B is normally configured to make linear measurements. The RF source stimulates the amplifier under test (100 MHz in this example). The incident and test signals are received and mixed down to a low frequency IF (1 MHz). The 1 MHz IF signal is filtered to remove unwanted signals and then measured. The 1 MHz IF signal in the Reference (R) channel also goes to one input of a phase detector. The other input is fed by a stable 1 MHz frequency reference. The phase detector produces an output voltage which is proportional to the phase difference between the two input signals. This voltage is used to fine

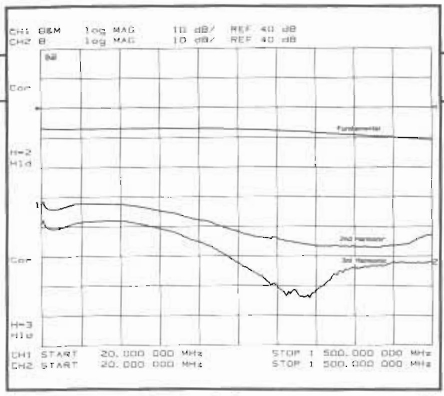


Figure 2a. Swept frequency amplifier measurement of absolute fundamental, 2nd and 3rd harmonic output level (dBc).

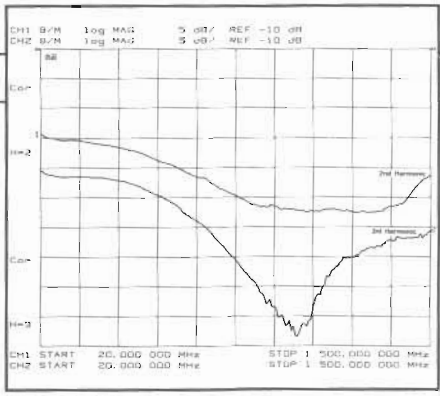


Figure 2b. Swept frequency amplifier measurement of 2nd and 3rd harmonic distortion (dBc).

tune the source to a precisely specified frequency. This particular block diagram is capable of measuring the signals only at the RF source frequency.

To measure nonlinear performance, such as an amplifier's second harmonic output level, a different configuration (shown in Figure 1b) is required. The incident stimulus frequency is used as the reference signal (again, 100 MHz) while the test channels is at two times the fundamental's frequency to measure the harmonic. By multiplying the LO frequency (99.5 MHz) in the output test channel by 2 (2 × LO = 199 MHz) the second harmonic (200 MHz) is mixed down to the receiver's desired 1 MHz IF. In the reference channel, the fundamental (100 MHz) is mixed down (LO = 99.5 MHz) to 0.5 MHz. When measuring the second harmonic, the phase detector reference signal is also 0.5 MHz. Measurement of either the fundamental, second or third harmonic signals, individually or as ratios (dBc), can be displayed.

Similar modification to the network analyzer's block diagram is necessary to measure a frequency translating device such as a mixer. An external frequency source is required to generate the LO signal. The HP 8753B's built-in source can be used as the mixer's RF stimulus with all of the receiver input channels tuned to the mixer's output IF (RF minus LO product only). In this case the analyzer's source is offset from the receiver by the specified LO frequency.

Amplifier testing

The majority of amplifier measurements are linear but many applications also require nonlinear information. Today, the typical configuration uses an external RF source to stimulate the amplifier at a CW frequency with a spectrum analyzer connected at the device output. The output spectrum of the amplifier is then displayed. This technique provides high dynamic range and the ability to measure total harmonic distortion (including all harmonics, spurious and intermodulation products).

The HP 8753B can now make a swept-frequency measurement of an amplifier's second or third harmonic as shown in Figure 2a. The second/third harmonic response can be displayed directly in dBc, or dB below the fundamental or carrier (see Figure 2b). The ability to display harmonic level vs. frequency or RF power allows "real-time" tuning of harmonic distortion. Further, this swept harmonic measurement, as well as well as all of the traditional linear amplifier measurements can be made without reconnecting the device to a different test configuration.

Vector network analyzers are commonly used to characterize amplifier gain compression vs. frequency and power level. This is essentially linear characterization since only relative level of the fundamental input to the fundamental output is measured. The narrowband receiver is tuned to a precise frequency and, as a result, is immune from harmonic distortion. Sometimes it is desired to quantify the harmonic distortion itself. Figure 3 illustrates a simultaneous measurement of fundamental gain compression and second harmonic power as a function of input power.

In a compression measurement it is necessary to know the RF input or out-

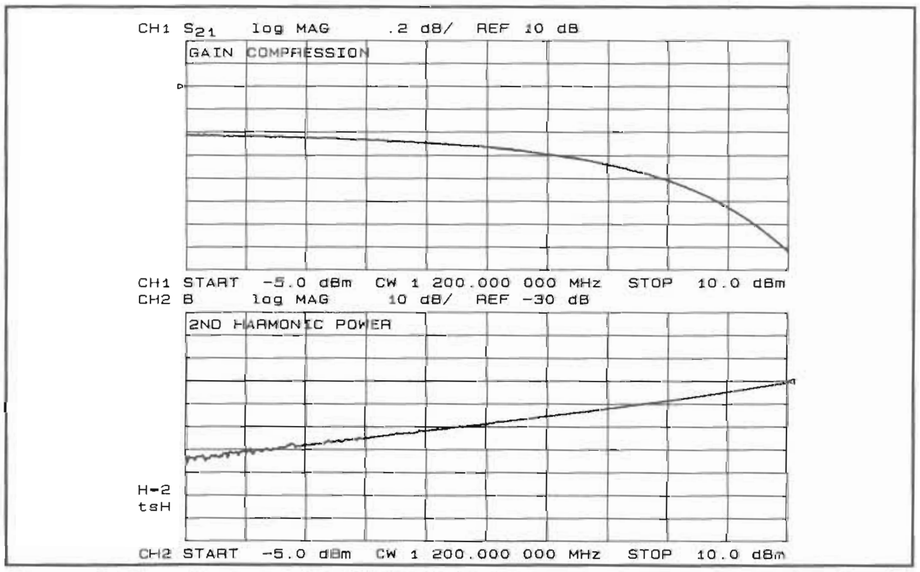


Figure 3. Swept-power measurement of an amplifier's fundamental gain compression and 2nd harmonic output level.

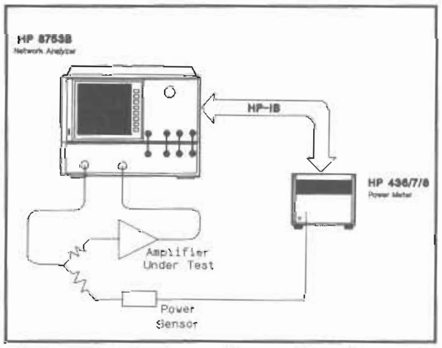


Figure 4. Test configuration for setting RF input using automatic power meter calibration.

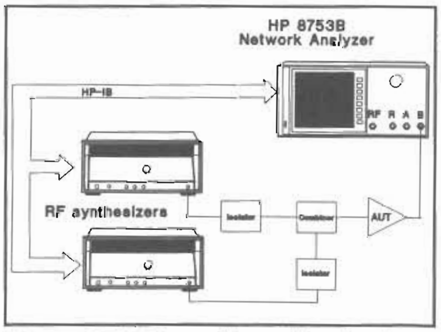


Figure 5. Test configuration for two-tone third-order intermodulation measurement.

put power at a certain level of gain compression. Therefore, both gain and absolute power level need to be accurately characterized. Uncertainty in a gain compression measurement is typically less than 0.05 dB. Also, each input channel of the HP 8753B is calibrated to display absolute power (typically within ±0.5 dBm up to 3 GHz, and ±1 dB up to 6 GHz).

However, when measuring a device that is very sensitive to absolute power level, it is important to be able to accurately set the power level at either the device input or output. Power meters are typically used to accurately monitor absolute power level. This presents an additional level of complexity, because the RF source must be re-adjusted to provide the correct signal level at the device's input or output. In automated production test areas, an external computer is often used to control both the network analyzer and the power meter. The HP 8753B is now capable of using an external HP-IB power meter and controlling source power directly. Figure 4 shows a typical test configuration for setting a precise leveled input power at the test device input.

Intermodulation distortion can also be characterized using the HP 8753B and two external RF sources. Figure 5 shows a typical configuration. The receiver is adjusted to measure the signals of interest, the two fundamental tones as well as the third order products. Because the receiver is not phase-locked to any of the incoming signals, the two external sources must be synthesized. Hewlett-Packard low cost RF signal generators, the HP 8653B or HP 8657A are recommended because of their frequency stability in this application. An example measurement third order intermodulation with a two tone stimulus is shown in Figure 6.

Mixer Testing

Mixers or frequency converters, by definition, exhibit the characteristic of having different input and output frequencies. For a single-sideband mixer measurement, the RF source can be offset in frequency from the input receiver frequency, allowing for a swept RF stimulus over one frequency range and measurement of the IF response over another (in this case the output IF). Figure 7 shows a suggested test configuration for the HP 8753B in the Frequency Offset mode. External signal separation schemes rather than two-port S-parameter test sets are generally required for testing multiple-port devices.

Attenuation at all mixer ports is used to reduce errors associated with port mismatches. IF filtering at the mixer's IF port is recommended to prevent unwanted mixing products from entering the receiver. The swept RF-to-IF conversion loss of a mixer with a fixed LO of 1500 MHz, is shown in Figure 8. In this same test configuration, conversion loss compression (loss vs. power level) can be measured on a single frequency basis by sweeping input power level. Stepped RF and LO frequency, fixed IF mixer testing can be achieved by stepping two external sources while measuring the output IF.

Amplitude and phase matching of mixers can be performed using the test configuration shown in Figure 9. The R channel mixer is used as part of the phase and amplitude reference. A second mixer is added to either the A or B input channel of the HP 8753B receiver. Using power splitters to divide the RF and LO signals between the reference and test mixers, comparative measurements are made by displaying the ratio of the test and reference channels.

Built-In Automation

As instrumentation becomes more complex and test requirements more exhaustive, it is even more important to maintain a balance between a simple operator interface and minimum test time. Complex test systems require more operator training and the possibility of human error increases as the number of steps in the test process increase. When production volumes are high enough, many test systems are completely automated to simplify and speed device testing. However, there are many low and medium volume test applications where automation would reduce test time but do not justify the initial cost of purchasing a computer and developing custom software.

The new Test Sequence function lets you automate a test without a computer and does not require any additional programming expertise. Operation is similar to programming a hand-held calculator. The HP 8753B simply "learns" the keystrokes normally used to make a measurement, which can later be executed with the push of a key. Each sequence can hold approximately 200 instructions. All of the analyzer's test features can be automated, augmented by some basic decision-making capability (i.e., IF LIMIT TEST FAILS, DO TUNE SEQUENCE). A simple example is shown in Figure 10. This sequence recalls a set-up, measures second harmonic in dBc, checks a test limit, and plots data if test limits are passed.

Another application of test sequencing is illustrated in one of the previous examples, The mixer test set-up in Figure 8 includes an external RF source to provide the LO signal. The test sequence function allows the HP 8753B to set the frequency and power of the RF source through the HP-IB interface. A similar application would be measurement of an RF amplifier at different bias levels automatically by controlling a programmable

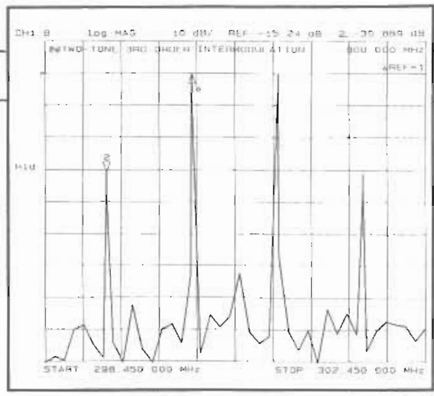


Figure 6. Measurement of third order intermodulation (TOI) products of an amplifier with a two-tone RF stimulus.

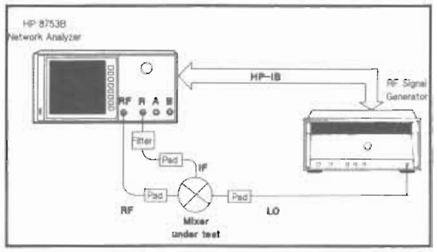


Figure 7. Mixer conversion loss test set-up.

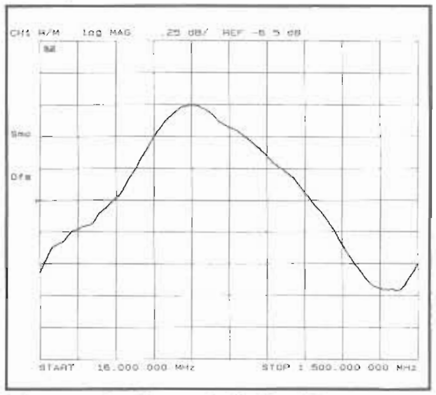


Figure 8. Swept RF-to-IF conversion loss measurement.

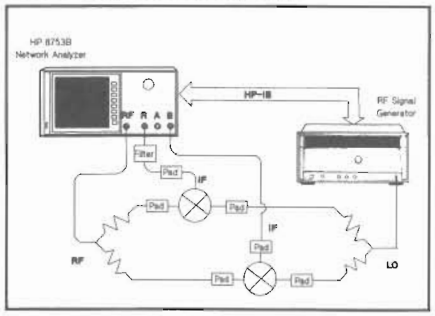


Figure 9. Test configuration for swept-frequency amplitude and phase tracking of mixers.

```
SEQUENCE AMPTEST
Start of Sequence
RECALL 3
HARMONIC OFF
DATA MEMORY
DATA/MEM
SECOND
LIMIT TEST ON
IF LIMIT TEST PASS THEN DO PLOT
IF LIMIT TEST FAIL THEN DO
  SEQUENCE 3
```

Figure 10. Example test sequence.

DC bias source.

The HP 8753B has a variety of new measurement capability and productivity enhancement features. Among these features are a built-in plotter/printer buffer and interpolative calibration (which allows the operating frequencies to be changed without recalibrating). However, just as important is the ability to configure a system that meets specific test requirements. A family of Transmission/Reflection and S-parameter test sets for 50 ohm (3 GHz) and 75 ohm (2 GHz) systems are available.

Alternatively, a complete 6 GHz system can be configured including the new HP 85047A 6 GHz S-parameter test set. This test set includes a frequency doubler that can be switched in to measure 3 MHz to 6 GHz in a single sweep or switched out to measure 300 kHz to 3 GHz. This test set exhibits less than 6 dB of insertion loss between the RF source and the test port for as high as 14 dBm output power at the test port in the 3 GHz band.

Optional time domain analysis, harmonic measurement capability and 6 GHz receiver operation can be added to any existing HP 8753A or 8753B network analyzer. An upgrade kit provides the hardware, software and documentation necessary to retrofit any existing HP 8753A.

Performance summary:

Frequency range (standard	300 kHz to 3 GHz
with Option 006 and HP 85047A	300 kHz to 6 GHz
Frequency resolution	1 Hz
Measurement range	
300 kHz to 3 GHz	0 dBm to −100 dBm
3 GHz to 6 GHz	0 dBm to −95 dBm
Dynamic accuracy (over a 40 dB range)	±.05 dB, ±0.3 deg
Harmonic measurement (Option 002)	
Frequency range	16 MHz to 3 or 6 GHz
Dynamic range	40 dBc

The HP 8753B family also includes other new products including a new HP 85024A 300 kHz to 3 GHz high impedance probe. Low input capacitance and high shunt resistance minimizes the loading to the circuit under test. The HP 8347A RF amplifier is capable of providing leveled power of +5 to +20 dBm with 25 dB gain over the broad 100 kHz to 3 GHz frequency range. The amplifier's ALC can be used to extend the dynamic range of the HP 8753B by 20 dB.

The HP 8753B is $25,500 U.S. list price and available May 1 with eight weeks delivery ARO. Harmonic measurement capability (add $3,000), 6 GHz receiver operation (add $3,000) and time domain analysis (add $4,800) are optional. The HP 85044A Transmission/Reflection test set is $3,500 and HP the 85046A S-parameter test set is $7,800. Both test sets cover the 300 kHz to 3 GHz frequency range and are currently available. The new HP 85047A 6 GHz S-parameter test set is $9,800 and is available May 1 with 16 weeks delivery ARO. The HP 85024A probe is $1,900 and is currently available. The HP 8347A RF amplifier is $3,750 and is available starting May 1.