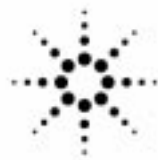# Notice

Hewlett-Packard to Agilent Technologies Transition

This documentation supports a product that previously shipped under the Hewlett-Packard company brand name. The brand name has now been changed to Agilent Technologies. The two products are functionally identical, only our name has changed. The document still includes references to Hewlett-Packard products, some of which have been transitioned to Agilent Technologies.

Agilent Technologies

User's Guide

HP 8510 Pulsed-RF Network Analyzer

HEWLETT PACKARD

Notice

The information contained in this document is subject to change without notice.

Hewlett-Packard makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. Hewlett-Packard shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this material.

Restricted Rights Legend.

Use, duplication, or disclosure by the U.S. Government is subject to restrictions as set forth in subparagraph (c) (1) (ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013 for DOD agencies, and subparagraphs (c) (1) and (c) (2) of the Commercial Computer Software Restricted Rights clause at FAR 52.227-19 for other agencies.

CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Institue of Standards and Technology (NIST, formerly NBS), to the extent allowed by the institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of delivery. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATIONS OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OR MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard Products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

Contents

Figures

1

Introduction

This document is intended for use with the HP 8510B/C Option 008 Network Analyzer and is a supplement to the HP 8510B/C Operating and Programming manual. It contains descriptions of the pulsed-RF network analyzer system features for measurements in the frequency domain and in the pulse profile domain. With respect to the standard, swept CW system, operation of the pulsed-RF system is identical except that the measurement is made at a specific, known time during each pulse. For information about network analysis, please refer to HP Product Note 8510-10, HP 8510B Introductory User's Guide, for an introduction to using the front panel for measurement setup, measurement calibration, and basic network measurements.

Organization of This Document

This section contains a list of the chapters in this document and a brief description of the contents of each chapter.

System Description

Introduces the HP 8510B/C Option 008 Pulsed-RF measurement capability.

Principles of Pulsed-RF Network Measurements

A list of the terms and definitions used in pulsed-RF network measurements.

Pulse Measurements Overview

A description of how the network analyzer measures pulsed-RF S-parameters versus frequency and versus time.

Operating the HP 8510 for Pulsed-RF Measurements

Describes the setup, measurement calibration, and measurement process for setting up the system and making pulsed-RF measurements.

Frequency Domain Point-in-Pulse Measurements

This chapter contains measurement calibration and measurement procedures to display the pulsed-RF S-parameters versus frequency.

Pulse Profile Domain Measurements

This chapter contains measurement calibration and measurement procedures to display the pulsed-RF S-parameters versus time.

General Timing Information

Descriptions of the internal timing to show the system's internal pulse repetition period and duty cycle capabilities.

Using External Triggering and Pulse Modulation

This section contains information to help you determine if your application requires external pulse modulating equipment, and instructions for connecting the external equipment.

High Power Measurements

Discusses the special considerations required to protect the test system and maintain accuracy when making measurements at high RF power levels.

Reference Data

Shows all option 008 menu structures and key definitions, including programming codes.

HP 8510C

HP 85110A

HP 83622A (RF)

HP 83624A (LO)
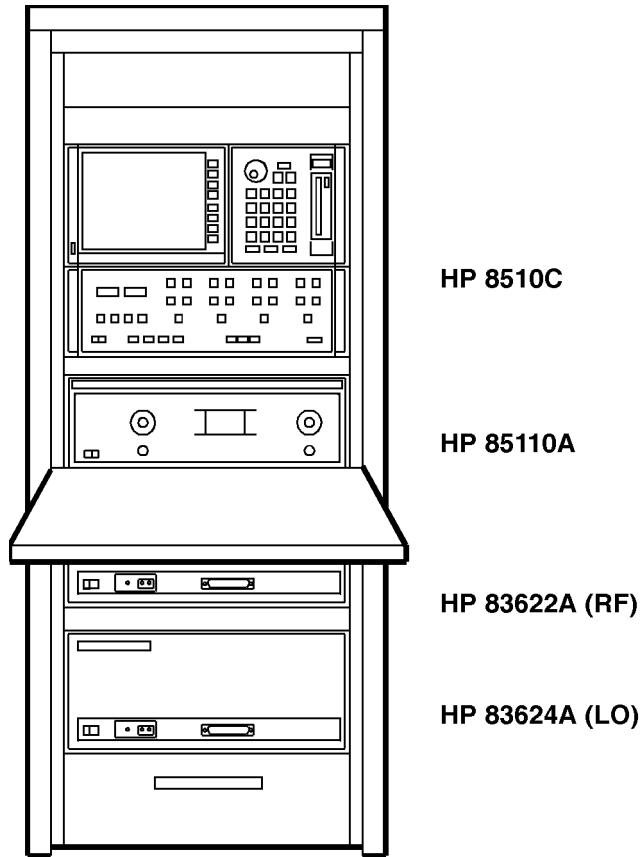
Figure 1-1. HP 8510 Pulsed-RF Network Analyzer System

2

System Description

This chapter contains the following information.

■ A description of the HP 8510 Pulsed-RF Network Analyzer System.

■ A simplified block diagram of the HP 8510 Pulsed-RF Network Analyzer System.

■ A signal flow diagram of the HP 85110-series S-parameter Test Set.

Who Should Make Pulsed-RF Measurements?

Pulsed-RF stimulus may be required in cases where continuous application of the test signal could destroy the device, such as when testing occurs prior to packaging, or where the device must be tested using a PRF and duty cycle that accurately represents its final application. The HP 8510 pulsed-RF network analyzer configuration adds specialized hardware and an optimized firmware feature set to make fully error-corrected S-parameter measurements of pulsed-RF responses. For the first time, the combination of wideband IF and accurate timing circuits provides precise synchronization with the pulse, allowing S-parameters to be measured at a precisely known, repeatable time during the pulse. This extends the HP 8510 applications into two major areas: tests in which the stimulus signal to the device is pulsed, and tests of devices which accept a CW input and produce a pulsed output.

The HP 8510 pulsed-RF network analyzer system allows you to calibrate in the same environment as your measurement. For example, if you are making a high power, pulsed-RF measurement, you can calibrate in the same high power, pulsed-RF mode. Calibration data is taken only while the pulse is on. This type of calibration may prevent damage to calibration standards that would be damaged in high power, CW calibrations.

The recommended configuration of the HP 85108 Pulsed-RF Network Analyzer consists of the following items.

■ HP 8510B/C network analyzer equipped with Option 008, Wideband IF, and HP 8510 firmware revision B.05.11 or greater (for the HP 8510B), or revision C.06.54 or greater (for HP 8510C).

■ HP 83622 synthesized sweeper with options 001, 003, 004, and 008.

■ HP 83624 synthesized sweeper with options 003, 004, and 008.

■ HP 85110-series pulsed-RF fundamentally mixed S-parameter test set

Also, other external equipment such as power amplifiers, bias supplies and pulse generators may be included in the system.

The pulsed-RF network analyzer system allows you to select either the normal precision 10 kHz IF bandwidth or the new wideband 3 MHz IF bandwidth. The wide IF and detection bandwidth allows testing using pulses as short as 1 microsecond but with accuracy comparable to traditional non-pulsed measurements.

These system components may be rack-mounted or arranged on a desktop.

Theory of Operation

A simplified block diagram of the system is shown in Figure 2-1. One synthesizer provides the test signal stimulus to the RF input of the test set and the other provides the LO signal to the four frequency converters (only two are shown). The LO source is always tuned 20 MHz above the test signal source. The standard internal phaselock technique is not used; instead, a common 10 MHz frequency reference is used for both of these sources and the internal sample selection and timing logic in the HP 8510. These sources are considered to be coherent, thus generating the correct 20 MHz first IF and the correct clock frequency for the reference and test synchronous detectors. This eliminates the need to use the reference signal for receiver phaselock and allows all reference and test signals to be pulsed, thereby making fully error-corrected 2-port, pulsed-RF S-parameter measurements possible.
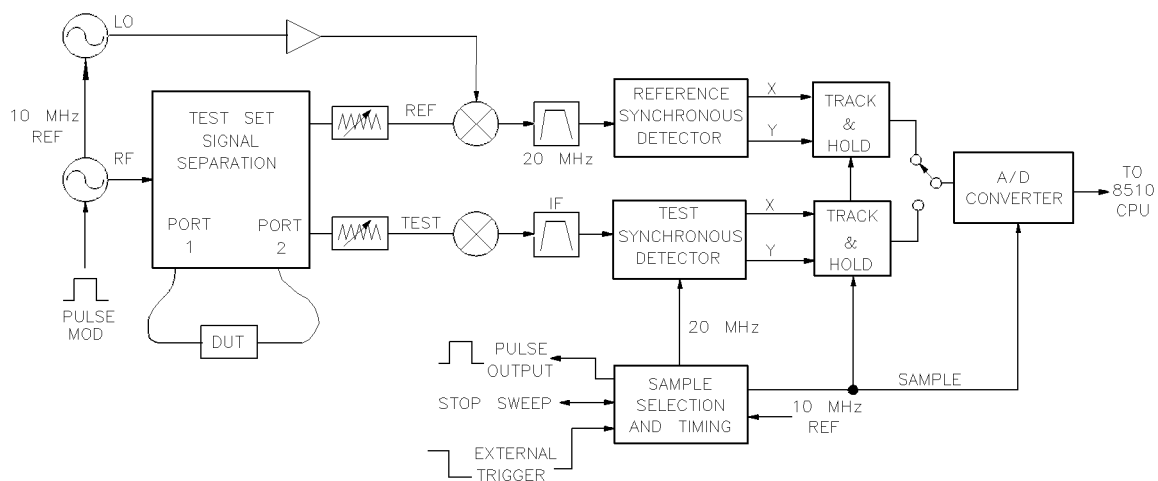
Figure 2-1. Simplified Pulsed-RF Network Analyzer Block Diagram

Using a wider bandwidth in both the reference and the test IF, synchronous detectors that operate at 20 MHz, and accurate measurement sample timing circuits allow flexible analysis of device response during the pulse. With the sources and test set controlled by the HP 8510 over the 8510 system bus, and with all necessary pulse generation and measurement timing signals generated internally from a common 10 MHz reference, the HP 85108 is a complete pulsed-RF stimulus/response test system. One pulse of a user-specified width is measured at each data point and the measurement is synchronized so that it is made at a certain known time in the pulse. The stimulus duty cycle can be predicted for a given instrument state, but the actual pulse repetition period depends upon the current domain, cal type, averaging, sweep time, and pulse width selections. For this reason, if your device is sensitive to duty cycle, refer to General Timing Information.

Either the internal logic, the TTL Trigger Input, or the HP-IB Group Execute Trigger from an external controller can initiate a measurement cycle. When control of the pulse repetition period and duty cycle is required, the HP 8510 can use the trigger input to synchronize with the internal or an external pulse modulator. The HP 8510 Stop Sweep output can be used as a gating signal to tell when the analyzer is ready for the next measurement. The measurement is made with 100 nanosecond resolution and about 200 picosecond uncertainty with respect to the internally- or externally-generated measurement trigger.

Test Set Signal Flow

Figure 2-2 shows a detailed diagram of the HP 85110-series test set signal separation, signal routing, and frequency conversion. This is a fundamentally mixed test set, providing four 20 MHz outputs to the network analyzer. Placement of a 0 to 90 db (10 dB/step) attenuator before each mixer provides control of the signal levels into the mixers while allowing operation at high PORT 1 and PORT 2 signal levels necessary in many pulsed-RF applications.

The test set has rear panel access links to allow integration of additional test and signal conditioning equipment in the low-loss main signal paths to the test ports. If your device exhibits more than about 20 dB of gain, or higher port signal levels are required, refer to the High Power Measurements chapter.

Hewlett-Packard harmonic mixing test sets are designed to work with the normal 10 kHz IF and detectors. These include the HP 8514, 8515, and 8516 coaxial test sets; and the HP 85104 millimeter waveguide test set. This HP 85110 fundamental mixing test set is designed to work with the wideband IF and detectors. There are applications in which the HP 85110 can be used with normal IF and detectors. The HP 85104 millimeter test sets can be configured to operate with the wideband IF and perform the pulse measurement functions described here.

All HP coaxial test sets can be equipped to include Option 001, IF Switching for Multiple Test Sets, so a system can be equipped for a wide range of applications by including up to four coaxial test sets and a millimeter-wave test set.
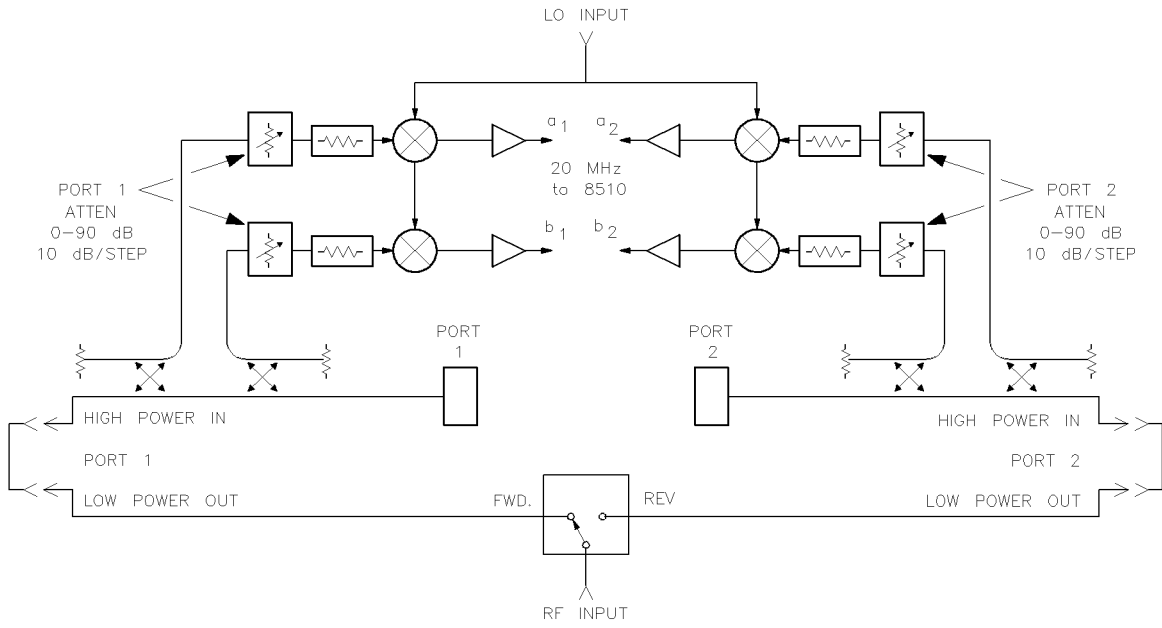
Figure 2-2. HP 85110A S-Parameter Test Set Signal Flow

3

Principles of Pulsed-RF Network Measurements

This chapter contains a list of terms used to describe the pulsed-RF stimulus and response. Figure 3-1 shows a typical envelope of the pulsed-RF waveform output by the RF signal source. For internal measurement triggering, the RF frequency and the ON time of the pulse is controlled by the HP 8510 so that there is one pulse per measurement.

Pulse Repetition Period, PRP

The time from the 50 percent point on the rising edge of one pulse to the 50 percent point on the rising edge of the next pulse.

For internal triggering operation the system PRP depends upon the instrument state. Typically there is one pulse per measurement. The pulse is turned ON for a user-specified time and the measurement is made at some user-specified time relative to the start of the pulse. The time until the next pulse consists first of the time required for the analyzer to set up for the next measurement and second, if necessary, waiting to satisfy the user-specified pulse width and duty cycle limit.

In the frequency domain, when the analyzer is tuned to the next frequency, the maximum PRP is about 30 milliseconds. In the Pulse Profile domain, the frequency does not change, making the maximum PRP about 3 milliseconds. With averaging, the PRP can be about 1 millisecond during part of the measurement. Other factors which affect the system PRP are calibration type, pulse width, duty cycle, and pulse profile domain stop time.

If the PRP is controlled externally, the HP 8510 external trigger input is used to synchronize the analyzer with the pulse.

Pulse Repetition Frequency, PRF

$$PRF = \frac{1}{PRP}$$

Duty Cycle

The ratio of the time that the pulse is ON to the total Pulse Repetition Period. If the pulse ON and OFF times are equal, the Duty Cycle is 50 percent.

For internal operation, the maximum duty cycle percent limit can be specified, but the actual duty cycle may be less, depending upon the user-specifed pulse width and the time it takes for the analyzer to set up for the next measurement.

Pulse Width

The ON time from the 50 percent point on the rising edge to the 50 percent point on the falling edge.

The internally-generated Pulse Width can be set from less than 100 nanoseconds to 40.88 milliseconds.

Rise/Fall Time

The pulse transition time:

tr = pulse rise time

The time it takes for the pulse to rise from the 10 percent ON condition to the 90 percent ON condition.

tf = pulse fall time

The time it takes for the pulse to fall from the 90 percent ON condition to the 10 percent ON condition.

The normal IF responds to rise/fall times of about 75 microseconds; the wideband IF responds to rise/fall times of about 300 nanoseconds.

Trigger Delay

The time after pulse ON that the measurement is actually made.

In the Frequency domain, the Trigger Delay can be set from down to -6 resolution periods (internal) or +3 resolution periods (external) and up to 40.88 milliseconds. In the Pulse Profile domain the trigger delay is automatic depending upon the display time span, pulse width, and number of points.

Pulse Profile Measurement Resolution Period

The time between adjacent Pulse Profile domain data points. The minimum is 100 nanoseconds. This is set by an algorithm depending upon the Pulse Profile stop time, pulse width, and number of time points.
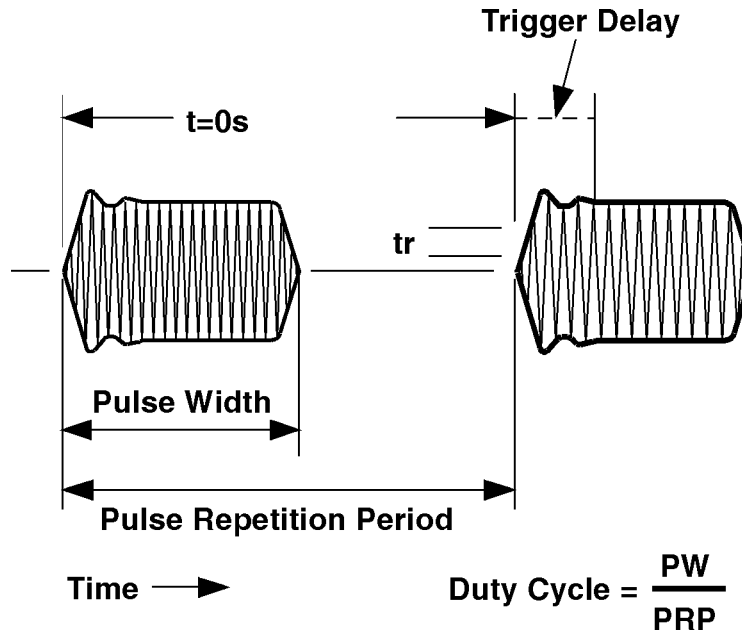
Figure 3-1. Pulse Terms and Definitions

$$Duty\ Cycle = \frac{PW}{PRP}$$

4

Pulse Measurements Overview

This chapter contains information about how the HP 8510 pulsed-RF network analyzer system measures pulsed-RF S-parameters versus frequency and versus time.

The pulsed-RF configuration allows use of vector network analysis techniques for two types of measurements:

- **Pulsed-RF S-Parameters versus Frequency**. The measurement is synchronized with the pulse so that the measurement result is the S-parameter at a specific user-specified point in the pulse at each frequency of the sweep

- **Pulse Profile**. The system is tuned to a single frequency and the measurement is synchronized with the pulse so that the measurement result is the S-parameter as a function of time during the pulse.

Pulsed-RF S-parameters versus Frequency

Pulsed-RF tests in the frequency domain are accomplished by synchronizing the measurement process with the pulse so that the measurement is made at a single, user-specified time during the pulse. At each frequency, the sources are tuned, the RF is turned on, then the measurement is made after a certain delay. Figure 4-1 shows an example of this "frequency domain point-in-pulse" measurement using the internal pulse output and the internal measurement trigger. For internal trigger mode, each data point of the trace represents the response of the device to the pulsed stimulus at the same interval after the pulse is turned on. For external trigger mode, each data point of the trace represents the response of the device to the pulsed stimulus after the falling edge of the externally-generated measurement trigger.
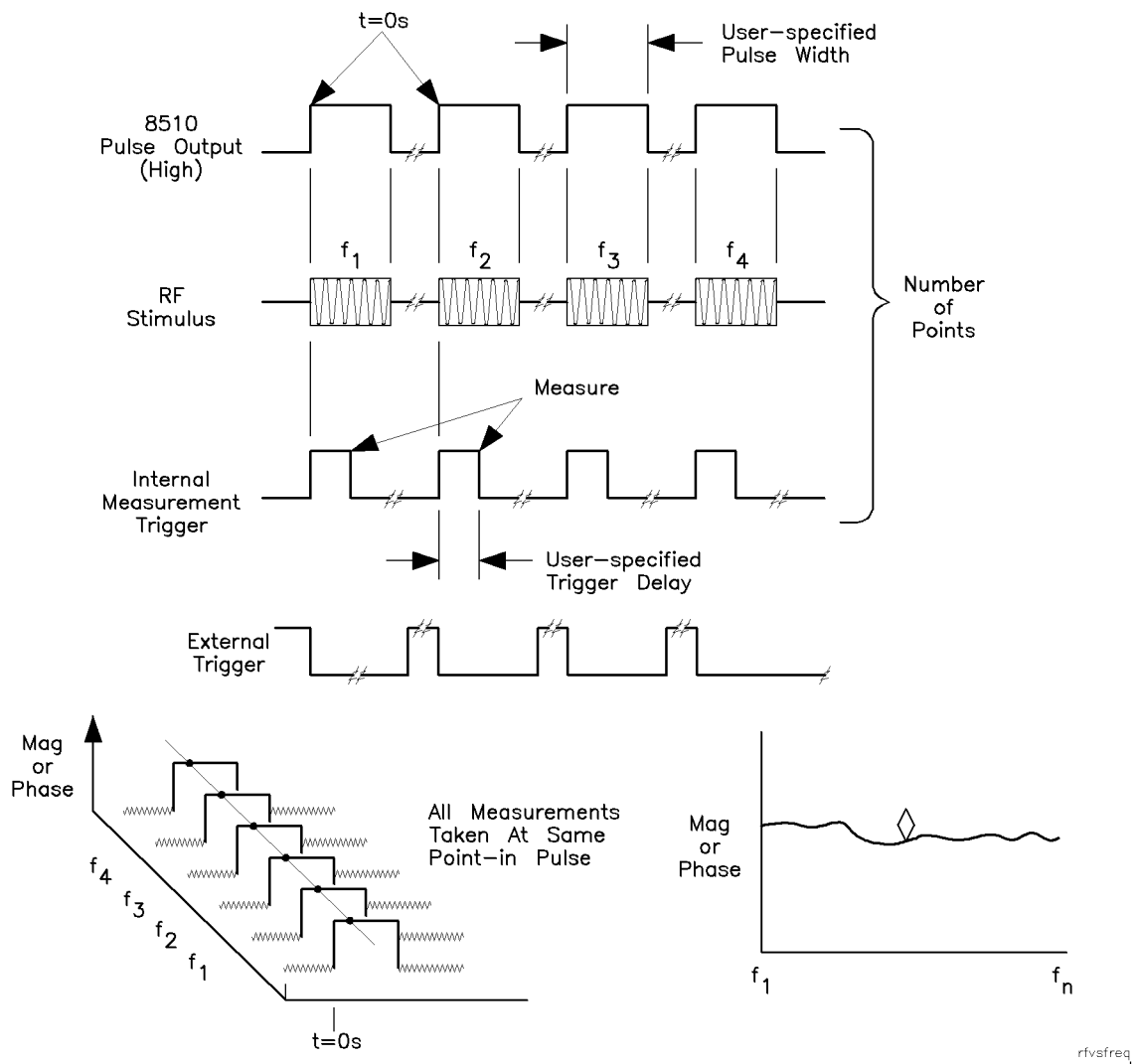
Figure 4-1. Pulsed-RF S-Parameters versus Frequency (Frequency Domain Point-in-Pulse)

Pulse Profile Domain

Measurements in the Pulse Profile domain create a plot of the response as a function of time in synchronization with the internal or the external measurement trigger. A repetitive sampling technique is used, in which the data is reconstructed from samples taken from a series of pulses. This allows display of the S-parameters versus time during the pulse. Figure 6 is an example of this process showing a timing diagram using the internal pulse modulation and internal measurement trigger. For each pulse, a single point in the pulse is measured. A profile of the pulse is made by measuring the first pulse at the user-specified Start time, then increasing the measurement trigger delay by a certain time increment for each pulse until the specified number of points is measured.

Time zero is the leading edge of the internally-generated pulse output waveform, or the falling edge of the externally-generated measurement trigger waveform. The HP 8510 automatically controls the time increment between samples, called the measurement resolution period, using an algorithm that depends upon the greater of the user-specified pulse width or stop time. This automatic selection of the time resolution can be seen by changing the number of points and the time span. For narrow pulses and small time spans, the measurement resolution period can be as small as 100 nanoseconds; for wide pulses and large time spans, it can increase to multiples of 10 microseconds. With the internal measurement trigger, the first sample can be taken up to 6 resolution periods prior to time zero. When using external triggering, the external trigger sets time zero and the first sample can be taken three resolution periods after time zero.
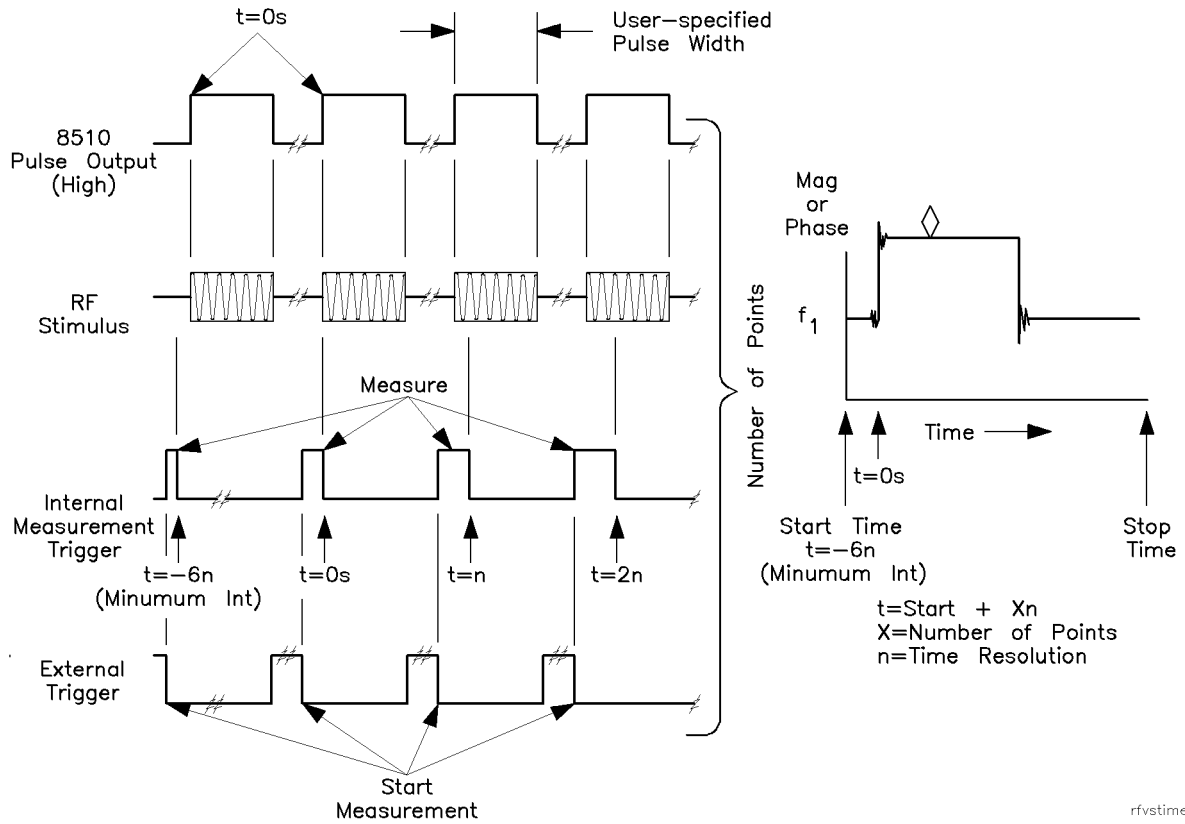
Figure 4-2.
Pulsed-RF S-Parameters versus Time (Pulse Profile Domain) Measurement
Internal Pulse Output and Internal Measurement Trigger

5

Operating the HP 8510 for Pulsed-RF Measurements

This chapter describes the setup, measurement calibration, and measurement process for configuring the system and making frequency domain point-in-pulse measurements and pulse profile domain measurements. These procedures use the internal pulse modulation and internal measurement trigger capabilities of the HP 8510 Option 008. Familiarize yourself with these capabilities before setting up measurements that use external triggering techniques.

For more detailed information on the standard features of the HP 8510, refer to the HP 8510 Operating and Programming manual.

System Connections

Figure 5-1 shows the cable connections for the recommended HP 85108 pulse configuration. Notice that the RF source serves as the 10 MHz frequency reference for the system, although the reference can be the LO source or the HP 8510. Many applications will also include bias supplies, amplifiers connected to the test set rear panel links, external pulse generators and modulators, and a computer. Verify these basic connections and familiarize yourself with other equipment that may be connected to the system.

HP 85101

8510 INTERCONNECT

IF/DISPLAY INTERCONNECT

To Plotter, Printer
(IF used)

J2 IF/DISPLAY INTERCONNECT

LINE MODULE

To Controller
(IF used)

LINE MODULE

HP 85102

J10 TEST SET INTERCONNECT

10MHz IN

PULSE OUT

STOP SWEEP

HP 85110A

LO INPUT

RF INPUT

LINE MODULE

J11 TEST SET INTERCONNECT

J12 8510 SYSTEM BUS

PULSE INPUT

**HP 83622A
RF SOURCE**

RF OUTPUT

10MHz REF OUTPUT

STOP SWEEP IN/OUT

LINE MODULE

HP-IB

**HP 83624A
LO SOURCE**

RF OUTPUT

10MHz REF INPUT

LINE MODULE

HP-IB

Figure 5-1. System Cable Connections

Turn On System Power

Turn on rack power, line power to the sources, test set, and other equipment, and then the HP 8510. Depending upon the contents of HP 8510 Instrument State 8 and the current HP 8510 Hardware State, the system may not be fully operational immediately after initial power up. Messages to the operator may appear on the screen and beep sounds may be heard. If so, load the pulse instrument state and hardware state as described below. The firmware revision will be displayed on the screen. It should be B.05.11 or later for HP 8510B, and C.06.54 or later for HP 8510C.

Load Pulse Hardware State and Instrument State Files

The pulsed-RF configuration files are supplied with the option 008 equipment. Use the following procedure to load the hardware state file 8 and the instrument state all file 8 into HP 8510 memory.

1. Load the configuration tape/disk.

   Press (TAPE/DISC) STORAGE IS TAPE/DISC .

2. Load pulse hardware state.

   Press LOAD MORE HARDWARE STATE FILE 8 .

   The M enhancement annotation should appear at the left side of the screen. This shows that the HP 8510 is operating in the multiple source mode.

3. Load pulsed-RF instrument state into inst. state 8.

   Press LOAD INST. STATE 8 FILE 8 .

4. After loading the files, press RECALL INST. STATE 8 .

   Recalling instrument state 8 sets the correct instrument state for pulse operation.

   If the wideband IF is selected, a **W** annotation will appear at the left side of the screen. This shows that the wideband IF and detectors are selected and that the TTL signal at the HP 8510 rear panel PULSE OUTPUT connector is activated. Select the wideband IF by pressing the following keys.

5. Press (SYSTEM), MORE PULSE CONFIG DETECTOR: WIDE BW .

Note   Preset always selects DETECTOR: NORMAL BW .

If these files are not available, create the correct hardware state file and instrument state file as described in the Creating Pulse Hardware and Instrument States chapter.

▶S₁₁   log MAG
REF 0.0 dB
       10.0 dB⁄

(graph with hp logo, trace near center line with a dip)

START   2.0000000000 GHz
STOP   20.0000000000 GHz

25 FEB 91
16:22:08
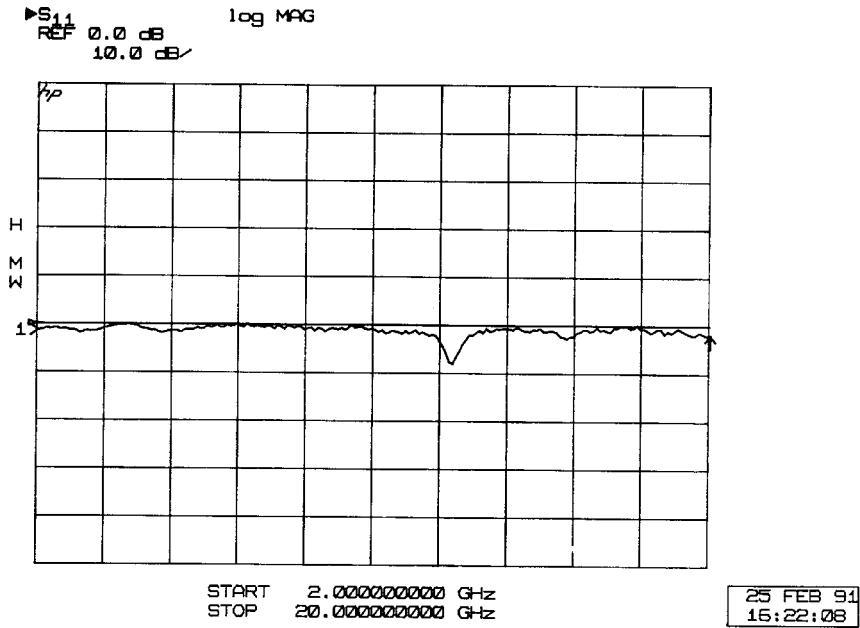
Figure 5-2.
Typical Response After Recall, Inst. State 8, Frequency, Detector: WB, Mult. Srce. On

▶S₁₁   log MAG
REF 0.0 dB
       10.0 dB⁄

(graph with hp logo, noisy trace)

START   -600.0 ns
STOP   19.4 µs

25 FEB 91
16:19:18
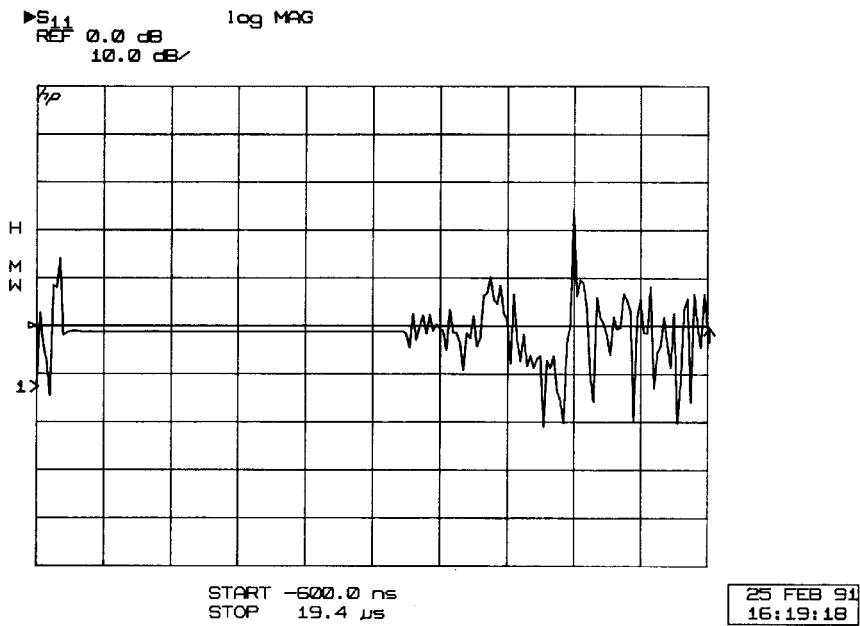
Figure 5-3. Domain, Pulse Profile, Marker

Operator's Check

After loading the pulse instrument state and hardware state files, then recalling instrument state 8, check operation of the pulsed-RF network analyzer (using internal triggering) by performing the following basic tests. Refer to the menu diagrams on the last pages of this document.

Pulse Profile Domain Check

1. Connect a short circuit to port 1 of the test set.

2. Press [PARAMETER] MENU USER a1 . You are viewing the unratioed value of the a1 reference signal.

3. Press [DOMAIN] PULSE PROFILE . The signal level is high when the pulse is On and low when the pulse is Off.

4. Press [MARKER] then move the marker to various points on the trace.

5. Press [SYSTEM] MORE PULSE CONFIG PULSE WIDTH .

6. Change the pulse width value. Notice that as you increase the pulse width past a certain point, the measurement time for each data point will increase.

7. Press DUTY CYCLE , then change the the duty cycle limit. This sets the maximum duty cycle percent allowed by the internal measurement timing logic. Notice that combinations of long pulse width and low percent duty cycle will increase the measurement time for each data point.

8. Press [STOP], then change the Stop time. Adjust the pulse width, number of points, and the stop time to achieve the desired display.

9. Press [SYSTEM] MORE PULSE CONFIG PULSE OUT: LOW . Notice that the polarity of the pulse changes.

10. Press PULSE OUT: HIGH .
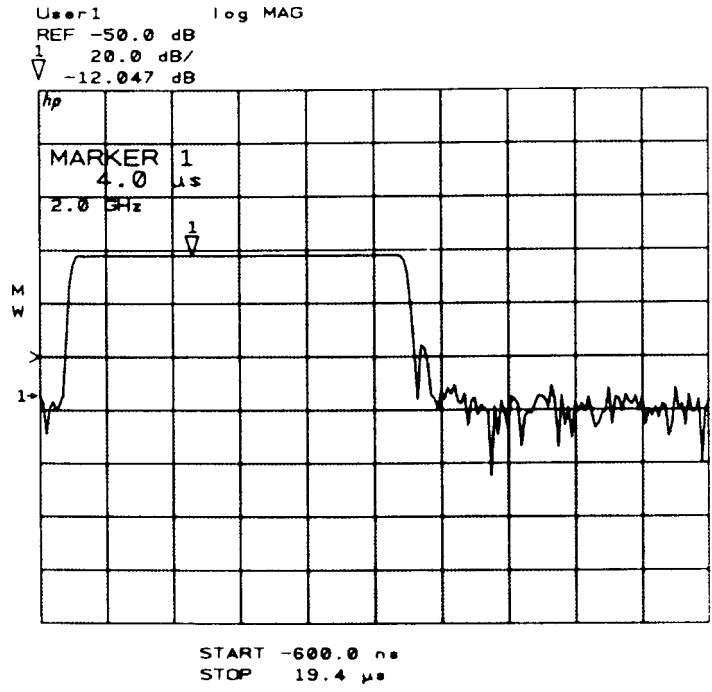
Figure 5-4. Pulse Profile, User1 a1, Marker

1. Press S_{11} to view the ratioed measurement. Notice that the trace is flat when the pulse is On and noisy when the pulse is Off.
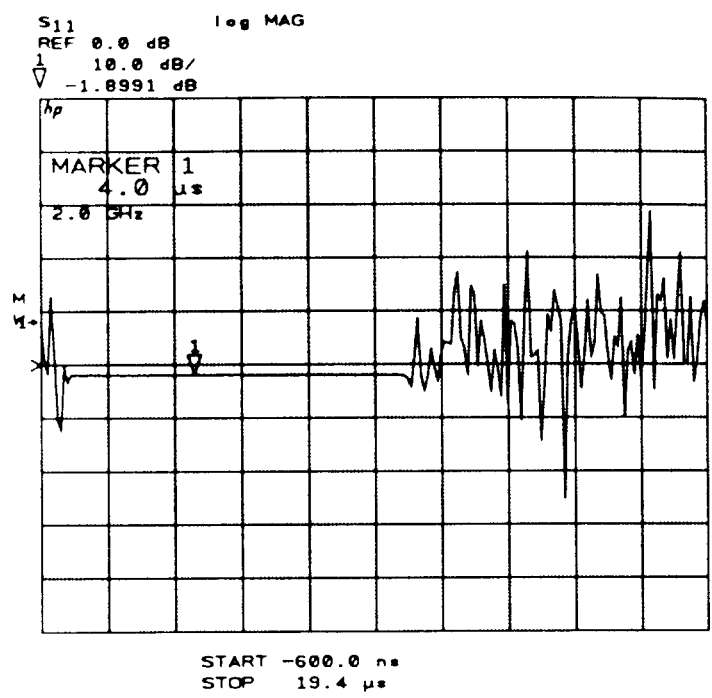
Figure 5-5. Pulse Profile, S_{11}

This occurs because when the pulse is Off, the network analyzer is measuring the ratio of noise to noise, and since the noise is approximately equal in the reference and test signal paths, the result is near 0 dB with respect to the On period of the pulse. Also, in this measurement, some large spikes may be seen in the noisy part of the trace. If the noise in the reference channel instantaneously goes to a very small value, the ratio will increase to a very large value.

Note   In the Pulse Profile domain:

- Without averaging, pulse width and duty cycle settings resulting in less than about 3 milliseconds PRP will not change the actual system PRP.

- With averaging, pulse width and duty cycle settings resulting in less than about 1 millisecond PRP will not change the actual system PRP.

Also, the PRP and duty cycle can vary during the sweep. To learn more about control of these values, refer to the General Timing Information chapter.

Frequency Domain Check

1. Press (DOMAIN) FREQUENCY .

2. If the W annotation does not appear, press (SYSTEM) MORE PULSE CONFIG DETECTOR: WIDE BW .

3. Press (MARKER), then move the marker to various points on the trace.

4. Press PULSE WIDTH and set the pulse width to 10 microseconds.
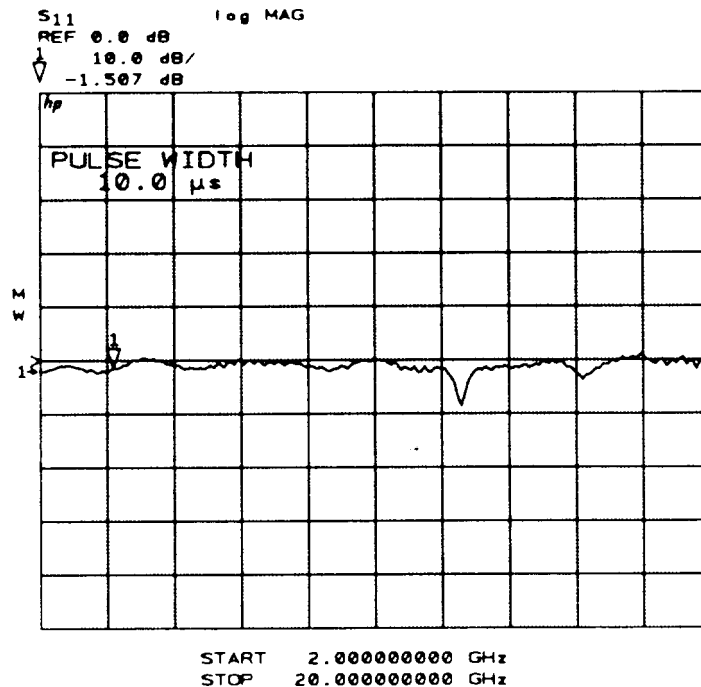
Figure 5-6. S_{11}, Frequency Domain, Pulse Width 10 μs, Trigger Delay 5 μs

1. Press (STIMULUS MENU) `MORE` `TRIGGER MODE` `TRIGGER DELAY`.

Change the trigger delay and notice that when the trigger delay is greater than the pulse width, the trace level decreases to the noise floor because the measurement is being made after the pulse has turned Off.
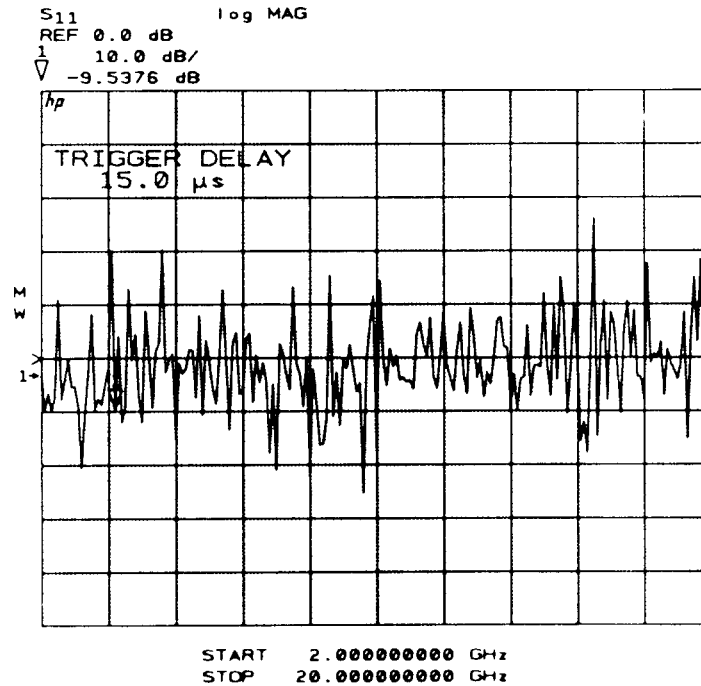
Figure 5-7. S$_{11}$, Frequency Domain, Pulse Width 10 μs, Trigger Delay 15 μs

1. Press (SYSTEM) `MORE` `PULSE CONFIG` `PULSE WIDTH`. Change the pulse width value. Notice that as you increase the pulse width past a certain point, the measurement time for each data point will increase.

2. Press `DUTY CYCLE`. Change the the duty cycle limit. This changes the maximum duty cycle percent allowed by the internal measurement timing logic. Notice that combinations of long pulse width and low percent duty cycle will increase the measurement time for each data point.

Note   **Frequency Domain System Duty Cycle**

In the Frequency domain:

■ Without averaging, pulse width and duty cycle settings resulting in less than about 30 milliseconds PRP will not change the actual system PRP.

■ With averaging, pulse width and duty cycle settings resulting in less than about 1 millisecond PRP will not change the actual system PRP.

To learn more about control of these values, refer to the General Timing Information chapter.

External Triggering Check

■ Connect the output of the external pulse generator to the HP 8510 rear panel TRIGGER IN connector and to the RF source PULSE MODULATION INPUT (Figure 9-1). Set the pulse generator to deliver a continuous TTL pulse train, going low for at least 100 nanoseconds at any pulse repetition period less than about 1 millisecond. Activate the pulse generator pulse output.

■ Press (STIMULUS MENU) MORE TRIGGER MODE TRIGGERING EXTERNAL .

The network analyzer should sweep normally in either the frequency domain or the pulse profile domain. The analyzer is not affected by excess trigger inputs.

■ Press (DOMAIN) PULSE PROFILE . The trace represents the signal at the RF source Pulse Modulation Input. The signal level is high when the pulse is On and low when the pulse is Off.

■ Press (MARKER) then move the marker to various points on the trace.

Adjust the time span and number of points for the desired display. Notice that the measurement resolution period is set by the pulse width, stop time, and number of points.

■ Press (DOMAIN) FREQUENCY . If the W annotation does not appear, press (SYSTEM) MORE PULSE CONFIG DETECTOR: WIDE BW .

■ Press (MARKER) then move the marker to various points on the trace.

In the frequency domain, adjust the trigger delay so that the measurement takes place at the desired time after the falling edge of trigger in.

You may also monitor the rear panel STOP SWEEP output with an oscillosope. Stop Sweep goes high to indicate that the HP 8510 is ready to make the measurement. Change the period of Trigger In and Pulse Modulation Input and notice the timing of the Stop Sweep. The HP 8510 Pulse Output is not active when external triggering is selected.

6

Frequency Domain Point-in-Pulse Measurements

This chapter contains measurement calibration and measurement procedures to display the pulsed-RF S-parameters versus frequency.

Measurement Calibration for Point-in-Pulse

Measurement calibration for point-in-pulse is accomplished in exactly the same way as for the standard HP 8510.

1. Press (DOMAIN) FREQUENCY to select the frequency domain. If the **W** annotation is not displayed, select the wideband detector by pressing (SYSTEM) MORE PULSE CONFIG DETECTOR: WIDE BW.

2. Select the maximum number of points required for the measurement, then perform the appropriate measurement calibration.

Note for internal triggering, when you press the key to measure the calibration standard, the HP 8510 pulse output signal is set to the active state (RF always On) during measurement of the standard. This assures that the calibration is made with respect to the On portion of the pulse independent of the trigger delay.

Note for external triggering, you control the pulse width and duty cycle during calibration and measurement. You must set the trigger delay to make the measurement at the correct time during the pulse for calibration, then not change it during the measurement.

Measurement

Set Pulse Polarity

After instrument preset, the pulse polarity is set to High for the On period of the pulse appearing at the HP 8510 rear panel PULSE OUTPUT connector. Use the following procedure to set the pulse polarity.

■ Press: (SYSTEM) MORE PULSE CONFIG PULSE OUT: HIGH or PULSE OUT: LOW.

Set Pulse Width

After instrument preset, the pulse width is set to 10 microseconds. Use the following procedure to set a different pulse width.

- Press PULSE WIDTH. Use the knob, step keys, or numeric entry to set the desired pulse width.

Set Duty Cycle Limit

After instrument preset, the duty cycle limit is set to 10%. This means that the maximum duty cycle will never be allowed to be greater than 10 percent regardless of the pulse width.

- To set the duty cycle limit, press DUTY CYCLE on the Pulse Configuration menu. Use the knob, step keys, or numeric entry to set the desired maximum duty cycle limit. Note that the actual duty cycle may be less.

Set Trigger Delay

After Preset, the trigger delay is set to 5 microseconds. This means that the frequency domain measurement will take place 5 microseconds after time zero. Time equals zero seconds is when the HP 8510 pulse output goes to the active level turning on the pulse modulator. Use the following procedure to set the trigger delay.

- Press (STIMULUS MENU) MORE TRIGGER MODE TRIGGER DELAY, then use the knob, step keys, or numeric entry to set the desired trigger delay.

Notice that if the trigger delay is set to outside the time interval that the pulse is On, the trace is noisy due to low signal levels.

Connect the Device Under Test

Figure 6-1 shows the response of the device to the pulsed-RF stimulus over the current frequency sweep.

```
S21            log MAG
REF  0.0 dB
     20.0 dB/
     18.466 dB
```
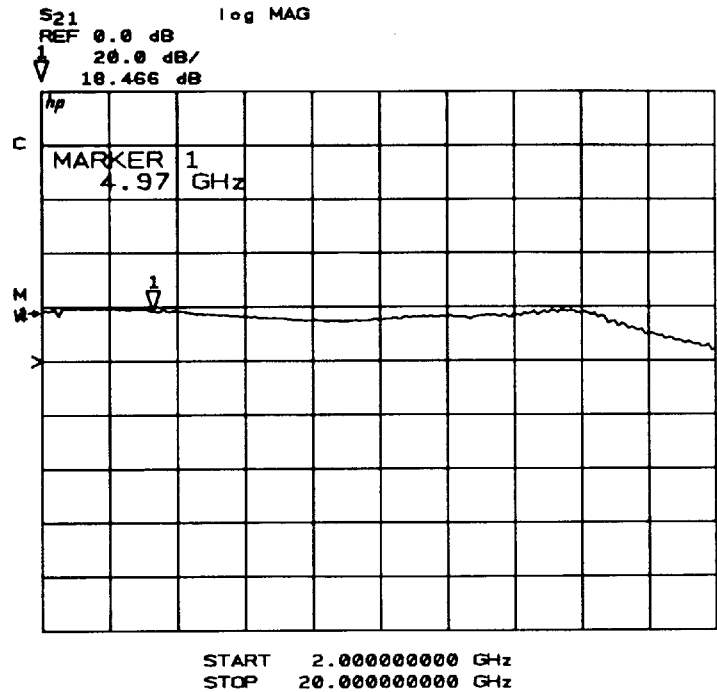
Figure 6-1. Amplifier Gain, Frequency Domain Point-in-Pulse

The dynamic range can be increased using IF averaging, but, given the system noise floor with the wide IF bandwidth, an averaging factor of about 256 averages is the maximum value that should be used. In general, using an averaging factor greater than 256 will not result in any increase in visible dynamic range.

7

Pulse Profile Domain Measurements

This chapter contains measurement calibration and measurement procedures to display the pulsed-RF S-parameters versus time.

Measurement Calibration for Pulse Profile

After selection of the pulse profile frequency, measurement calibration for pulse profile measurements is accomplished in exactly the same way as for the standard HP 8510. Following are two measurement calibration methods, one for calibration in the Pulse Profile domain, and the second for calibration using the Frequency List feature. Select the best one for your application.

The pulse profile domain calibration procedure is an easy way to familiarize yourself with the pulse profile domain and for general-purpose measurements using simple response-only correction.

Use the frequency list technique when more than one pulse profile frequency and 1-Port or 2-Port correction is required. Given adequate signal levels, accurate timing, and frequency stability, there is essentially no difference in the accuracy of the pulse profile measured data whether the calibration is performed in the pulse profile domain as described in the first procedure or in the frequency domain as described in the second procedure. The main advantage of calibration in the frequency domain is that you can calibrate at all frequencies in the list while only connecting the standards once.

Pulse Profile Domain

Perform measurement calibration in the pulse profile domain as follows.

1. Turn correction off by pressing (CAL) CORRECTION OFF .

2. Press (DOMAIN) FREQUENCY to select the frequency domain. Press (STIMULUS MENU) STEP to select the sweep mode.

3. Press (START) then set the start frequency to the desired pulse profile frequency. This will be the frequency measured when the pulse profile domain is selected.

4. Press PULSE PROFILE on the Domain menu. Press (MARKER) and notice that the active function readout shows both the time value at the marker position and the current measurement frequency.

5. Select the maximum number of points required for the measurement, then perform the appropriate measure- ment calibration.

   Note that the HP 8510 pulse output is set to the active state (RF always On) during measurement of the calibration standards. For external triggering, the pulse modulation is operating during the calibration, so the pulse width or time span cannot be changed after calibration.

6. For the next pulse profile frequency repeat this sequence.

With several cal sets created in this way, you can select each pulse profile frequency in turn by recalling the corresponding cal set.

Frequency Domain Using Frequency List

In the above measurement calibration procedure it is necessary to perform a separate calibration for each pulse profile frequency. This is not a problem for simple response-only calibrations, but when accuracy considerations require the use of 1-Port or 2-Port calibrations, connecting the necessary sequence of standards repeatedly can be tedious. As an alternative, the frequency list feature allows the standards to be connected once for all pulse profile frequencies.

Perform the calibration as follows.

1. Press [DOMAIN] FREQUENCY to select the frequency domain.

   If the **W** annotation is not displayed, the wideband detector must be selected before proceeding.

2. Press [SYSTEM] MORE PULSE CONFIG DETECTOR: WIDE BW .

3. Press [STIMULUS MENU] MORE EDIT LIST to display the Edit List menu. Create a segment for each pulse profile frequency to be measured. Each segment is defined such that the start and stop frequencies are identical and the number of points in each segment is the number of points to be displayed in the pulse profile measurement. For example, the following sequence creates a frequency list to measure four pulse profile frequencies, of 51 points each.

   a. Press ADD [START] [3] [G/n] NUMBER of POINTS [5] [1] [x1] DONE .

   b. Press ADD [START] [4] [G/n] [x1] DONE .

   c. Press ADD [START] [5] [G/n] [x1] DONE .

   d. Press ADD [START] [6] [G/n] [x1] DONE .

   e. Press DONE FREQUENCY LIST . The frequency list will be measured.

Figure 7-1 shows the resulting display. Proceed with the appropriate measurement calibration.
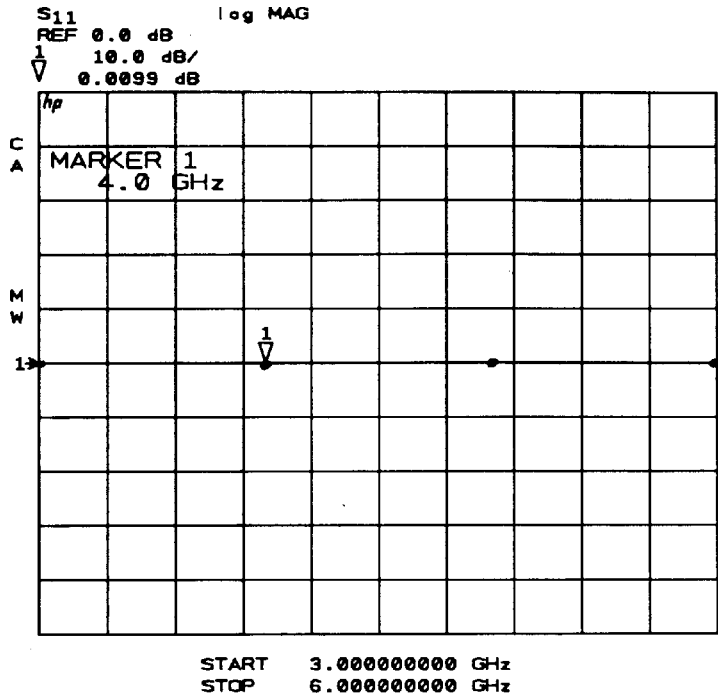
Figure 7-1. Frequency List Display During Measurement Calibration

4. Press (DOMAIN) PULSE PROFILE

5. Press (STIMULUS MENU) FREQUENCY LIST SINGLE SEGMENT .

The last selected segment will be active.
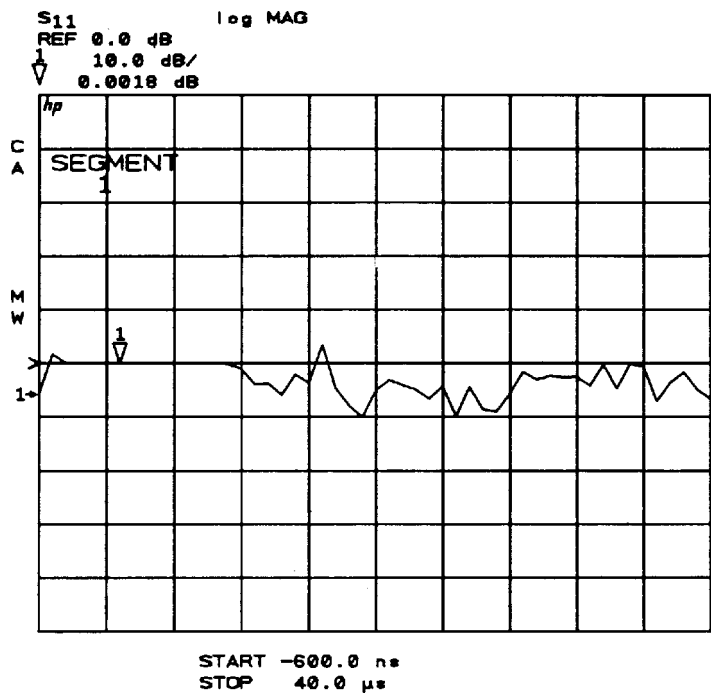
Figure 7-2. Pulse Profile, Frequency List Segment Number 1

6. To measure another frequency, select the appropriate active segment.

When either of these calibration procedures is complete, the device can be connected for measurement.

Again, in both of these procedures, note that when you press the key to measure the calibration standard, the HP 8510 pulse output is set to the active state (RF always On) during measurement of the standard. This ensures that the calibration data at every point is with respect to the On portion of the pulse.

Measurement

After calibration, first view the response of one of the calibration standards. Figure 7-3 is typical: the trace is flat at 0 dB when the pulse is On, and noisy around 0 dB when the pulse is Off. The noise during pulse Off will vary depending upon the relative signal levels in the reference and test signal paths.
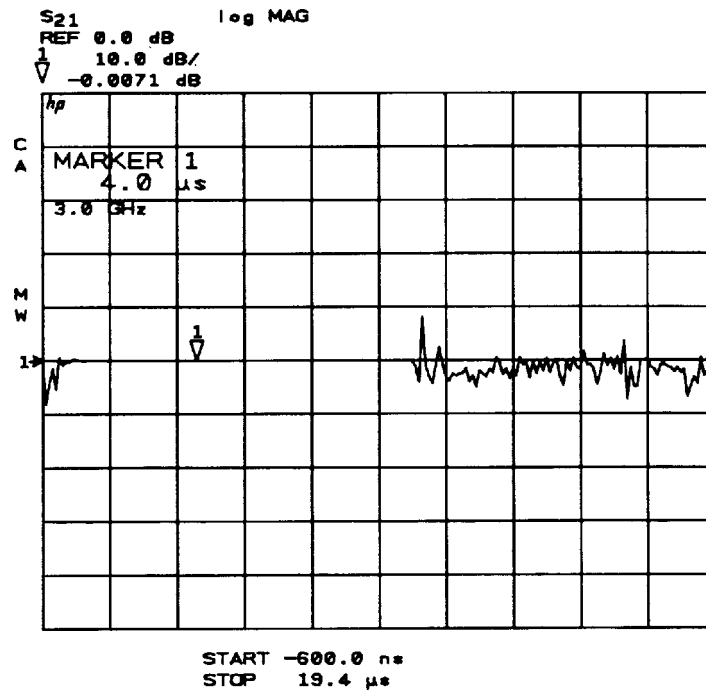
Figure 7-3. S_{21}, Pulse Profile, Thru

Set Pulse Polarity

After instrument preset, the pulse polarity is set to High for the On period of the pulse appearing at the HP 8510 rear panel PULSE OUTPUT connector. Use the following procedure to set the pulse polarity.

■ Press (SYSTEM) MORE PULSE CONFIG PULSE OUT: HIGH or PULSE OUT: LOW.

For internal pulse modulation and internal triggering, time equals zero seconds is always the point where the pulse transitions to the active level. The internal pulse modulator in the RF source turns the RF pulse On when the analyzer output is positive, so the noisy part of the trace will change location depending on the pulse polarity.

Set Pulse Width

After instrument preset, the pulse width is set to 10 microseconds. To set a different pulse width:

■ Press (SYSTEM) `MORE` `PULSE` `CONFIG` `PULSE` `WIDTH`.

■ Use the knob, step keys, or numeric entry to set the desired pulse width.

Set Duty Cycle Limit

After instrument preset, the duty cycle limit is set to 10%. This means that the maximum duty cycle will never be allowed to be greater than 10 percent regardless of the pulse width.

To set the duty cycle limit, press `DUTY` `CYCLE` on the Pulse Configuration menu. Use the knob, step keys, or numeric entry to set the desired maximum duty cycle limit. Note that the actual duty cycle may be less.

Set Measurement Time Span

The HP 8510 automatically chooses the minimum possible (given the HP 8510 hardware and firmware capabilities) time between samples, and thus the measurement resolution period, depending upon the larger of the pulse width time or the stop time. This results in a minimum possible span time which depends upon the current number of points.

To view the pulse with minimum sample resolution period and thus the best time resolution, press (STOP), then repeatedly press the ▼ key until the time value at the bottom of the grid does not change (or enter (STOP) (0) (x1)). This also sets the start time to the minimum value. If the pulse is longer than this time span, increase the stop time to view the entire time period of interest.

Set Measurement Resolution Period

To find the resolution period, press (MARKER), then move the marker one data point and see the time change in the Active Entry area. If necessary, adjust the resolution period to the value required for your measurement by changing the stop time, pulse width, and number of points.

Connect the Device under Test

With the pulse width set, connect the device under test. Figure 7-4 shows the response of the device to the pulsed-RF stimulus at the current frequency.

S11   log MAG
REF 0.0 dB
1   10.0 dB/
V   -5.5242 dB

hp

C
A   MARKER 1
       4.7 μs

5.0 GHz

M
W

START -600.0 ns
STOP   19.4 μs
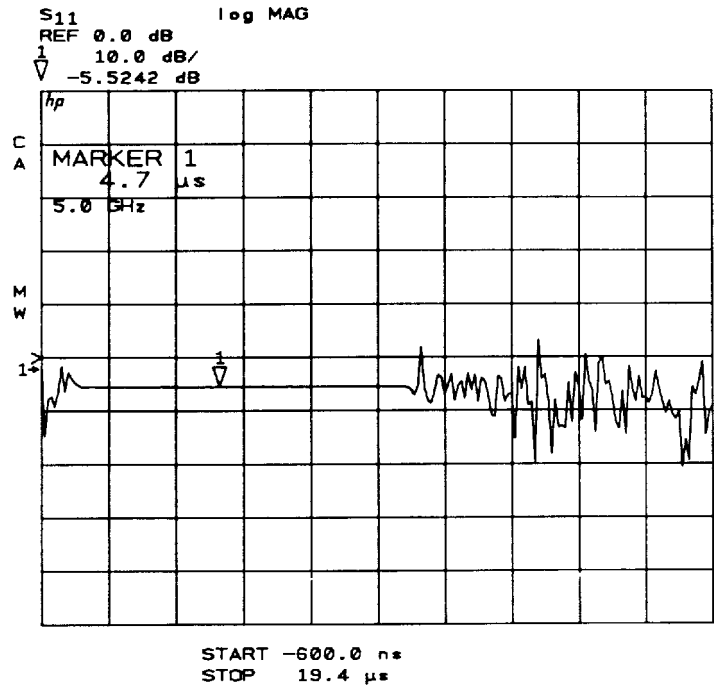
Figure 7-4. Minimum Time Span, Resolution Period = 100 ns

To measure another frequency, recall the appropriate cal set or frequency list segment, depending upon the calibration procedure used.

Figure 7-5 shows the S_{11} response using the Smith chart format. The marker is showing the input impedance during the On time of the pulsed-RF stimulus.

S11   Z
REF 1.0 Units
1   200.0 mUnits/
V   32.484 Ω   -47.15 Ω

hp

C
A   PULSE WIDTH
       25.0 μs

M
W

START 5.0 μs
STOP   25.0 μs
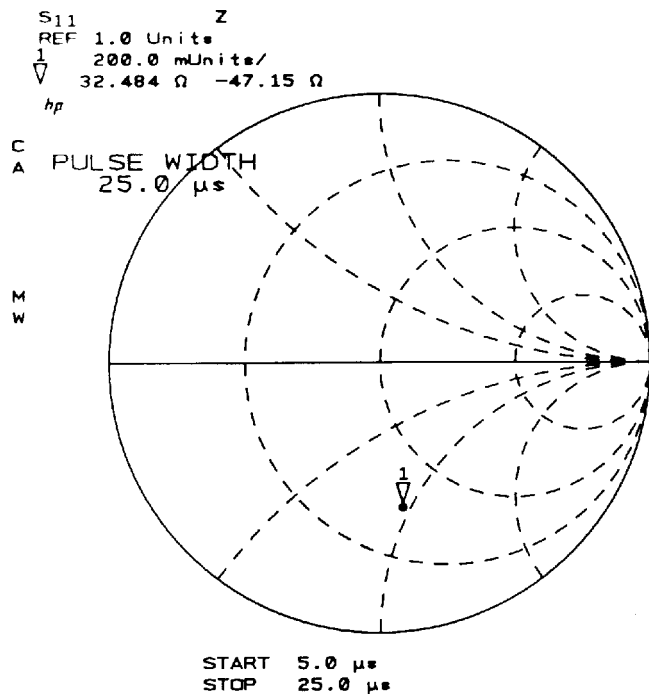
Figure 7-5. S_{11}, Smith Chart

Switching Between Frequency Domain and Pulse Profile Domain

The domain in which the measurement calibration was performed is not part of the cal set limited instrument state. This means that, for example, a cal set created in the frequency domain could be turned on for a pulse profile domain measurement with no message to the operator. Except for the pulse profile calibration procedure in the frequency domain using Frequency List, a cal set should only be used in the domain in which it was created.

Press the following keys to switch between the frequency domain and the pulse profile domain.

- (CAL) CORRECTION OFF (DOMAIN) FREQUENCY or PULSE PROFILE

- (CAL) CORRECTION ON CAL SET n

This sequence makes certain that the cal set applies to the domain in which it was created. Another method is to save a number of instrument states, each with the appropriate domain and cal set, then simply recall the desired instrument state.

If a cal set created in the pulse profile domain is turned On while in the frequency domain, it is treated as if the calibration were performed using step sweep with the minimum frequency span. The pulse profile domain error coefficients are applied to different frequency points, resulting in trace errors.

Also, if a cal set created in the frequency domain is turned On while in the pulse profile domain, the frequency is set to the start frequency of the frequency domain cal set and the frequency domain error coefficients are applied to each corresponding point in the pulse profile domain. This also results in trace errors.

8

General Timing Information

Previous examples have used the internal measurement trigger and the internal pulse generator to demonstrate basic operation of the network analyzer. This setup is suitable for many applications in which the internal PRP and maximum duty cycle limitations are not critical to measurement results. If your device is sensitive to pulse repetition period or duty cycle you will need to learn more about how these are affected by the instrument state. The following paragraphs provide information that can be used to predict the internal PRP for different instrument states.

Network Analyzer Measurement Cycle

Figure 8-1 shows the general measurement process flow of the network analyzer measurement cycle. For the frequency domain point-in-pulse measurement and the pulse profile domain measurement, the HP 8510 measurement cycle consists of making the measurement, setting up for the next measurement, then waiting for the next trigger.
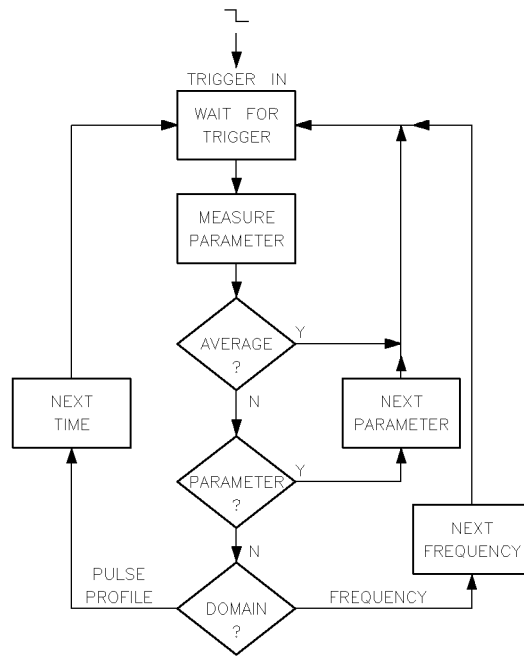
Figure 8-1. Network Analyzer Measurement Cycle

Each measurement cycle is initiated by the falling edge of the TTL signal at the rear panel external Trigger Input, or the internal 8510 logic, depending upon whether external or internal triggering is selected. At the appropriate time after the trigger, the measurement is made. If averaging is turned On but not completed, the process waits for the next trigger to make the next measurement for that data point. If averaging is complete but another parameter is required (2-Port correction is On), the next parameter is selected and the process waits for the next trigger. When all data for that point is acquired, then the process moves to the next point, changing the frequency if in the frequency domain, or the time if in the pulse profile domain, then waits for the next trigger.

These times are representative typical measurement cycle times using preset values for the analyzer controls.

Measurement Cycle Times

1 ms	Next Average
4 to 8 ms	Next Parameter
30 to 40 ms	Next Frequency Point (Frequency Domain)
3-4 ms	Next Time Point (Pulse Profile Domain)

Measurement Cycle Time

Controls that can effect the measurement cycle time are:

Sweep Time. When the analyzer is otherwise ready for the next measurement cycle, it ignores triggering for an interval equal to (Sweep Time (ms)/Number of Points).

Pulse Width. The pulse always remains On for the user-specified time.

Duty Cycle Limit. When the analyzer is otherwise ready for the next measurement cycle, if the duty cycle percent maximum limit would be exceeded, the process ignores triggering until the duty cycle limit is satisfied.

Pulse Profile Domain Stop Time. The time value of the current pulse profile data point determines the measurement cycle time when it is greater than the PRP set by the duty cycle limit.

Frequency Domain Trigger Delay. If the frequency domain trigger delay is greater than the duty cycle limit, trigger delay will control the minimum frequency domain measurement cycle time.

Additional considerations are:

■ Pulse Output is set to the active level during measurement of any calibration standard.

■ Pulse Output is set to the inactive level during the sweep retrace.

■ Pulse Output is set to the active level for less than 30 microseconds immediately prior to the beginning of the sweep for the automatic periodic IF calibration sequence.

■ Pulse Output remains at the inactive level under all conditions when External Triggering is selected.

The automatic periodic IF calibration sequence is transparent to the operator except for the less than 30 microsecond pulse output immediately prior to the beginning of a sweep. To the operator, the IF calibration sequence will appear to occur at random times, more frequently just after the HP 8510 is turned on, then less often as the system temperature stabilizes.

Pulse Repetition Period and Duty Cycle Considerations

From this information it can be seen that the pulse repetition period and thus the duty cycle of the pulsed-RF signal applied to the DUT can vary depending upon the instrument state. For measurements in which the PRP or duty cycle is not important, simply set the pulse width and the duty cycle controls to an appropriate value and make the measurement. The specified duty cycle limit will not be exceeded, but the actual duty cycle may be less than expected.

For example, Figure 8-2 shows the pulse output waveform for various conditions. Figure 8-2a shows the pulse output when the pulse width is 500 microseconds, the duty cycle limit is 50 percent, and averaging is off. Under these conditions the measurement cycle time is about 3 milliseconds per trace data point in the pulse profile domain, or about 30 milliseconds in the frequency domain. Figure 8-2b shows the same conditions with averaging on and an averaging factor of four. Now four measurements are taken for each data point with the measurement cycle time alternating between 1 millisecond for each of the measurements required for the averaging, and the time to move to the next data point. Figure 8-2c shows the measurement when 2-Port correction is On. Here, the parameter switching time also affects the overall PRP and duty cycle.
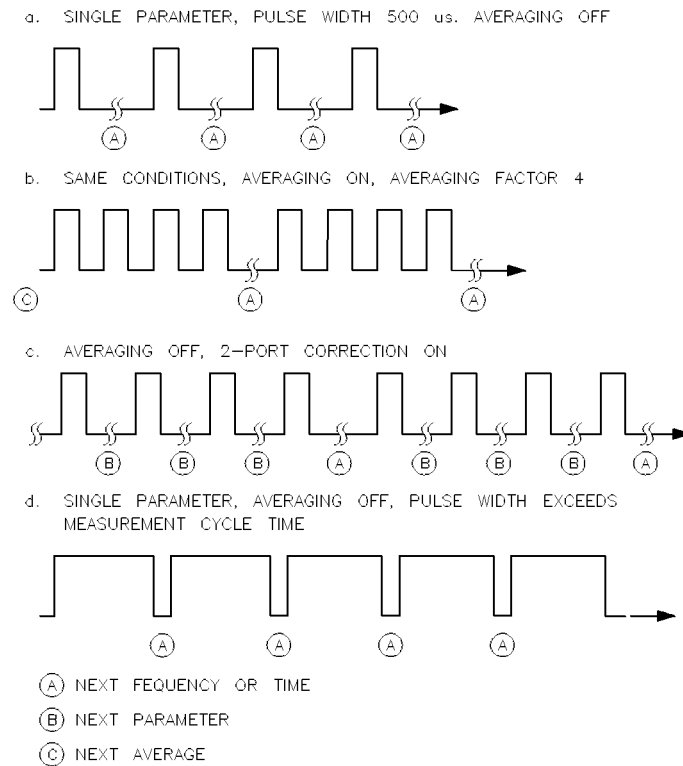
Figure 8-2. Example Internal Pulse Output PRP and Duty Cycle

In Figure 8-2, the pulse width is greater than the measurement cycle time, so the duty cycle could approach 100 percent. This is avoided by setting the duty cycle function to the maximum value allowed in the measurement. When the combination of the pulse width and the duty cycle limit approaches the measurement cycle time, the pulse off part of the measurement cycle time is increased to satisfy the duty cycle limit.

If you are viewing this with an oscilloscope, notice how the measurement cycle time varies according to the pulse profile stop time. If the stop time is greater than the pulse width, the measurement cycle time will extend past the end of the pulse depending upon the time value of the data point being measured. Depending upon the pulse width, this can result in a lower percent duty cycle toward the end of the time span.

External Trigger and Stop Sweep Signals

Figure 8-3 shows the relationship between the external Trigger Input and the HP 8510 Stop Sweep output for frequency domain point-in-pulse measurements and for pulse profile domain measurements. For external triggering, Stop Sweep remains Busy (low) until the measurement cycle is complete. This information is important for synchronizing the pulse modulation to the external trigger.

It is easy to learn the timing by using an oscilloscope to view Stop Sweep when the external trigger is applied.

Press (STIMULUS MENU) MORE TRIGGER MODE TRIGGERING EXTERNAL and apply a TTL pulse train to the HP 8510 rear panel EXTERNAL TRIGGER INPUT. The trigger should stay low for at least 100 nanoseconds. Excess triggers that occur while stop sweep is busy (low) are ignored. The next external trigger falling edge after stop sweep is ready will initiate the next measurement cycle and retrace is automatic.
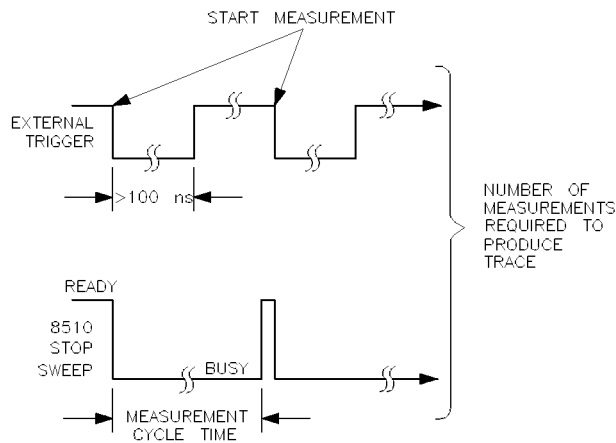
Figure 8-3. External Trigger and Stop Sweep Timing Diagram

When `TRIGGER MODE TRIGGERING INTERNAL` is selected, the stop sweep output does not operate (always in the ready state). Timing diagrams for the pulse output signal and development of the internal measurement trigger are shown in Figure 4-1 and Figure 4-2.

When `TRIGGER MODE TRIGGERING EXTERNAL` is selected, the falling edge of the external trigger input defines time equals zero seconds for each measurement cycle. Stop sweep falls immediately and stays low until the HP 8510 completes the measurement cycle and is ready to accept the next trigger. The time period that stop sweep remains busy depends upon the next measurement function to be performed. Pulse output is turned Off for external triggering. As for internal triggering, the pulse profile measurement resolution period is set by the larger of pulse width and pulse profile domain stop time.

9

Using External Triggering and Pulse Modulation

In applications where it is necessary to maintain close control over the PRP and duty cycle of the pulsed-RF stimulus, you can use external equipment to provide the TTL pulse modulation and external trigger signals. When using an external pulse modulation signal, it is necessary to synchronize the network analyzer with the pulse modulation signal so that the measurement is always made at the same time with respect to the stimulus. This synchronization is accomplished using the HP 8510 external trigger input.

Connect the Pulse Generator

A simple method to control the PRP and duty cycle of the pulsed-RF stimulus is to use an external pulse generator to provide the pulse modulation input to the RF source. Figure 9-1 shows a simple setup. In this example the same TTL pulse train provides the pulse modulation input to the RF source and to the HP 8510 rear panel TRIGGER IN connector. However, in your application it may be desireable to use different synchronized inputs to the network analyzer TRIGGER IN and to the pulse modulator.

Please note that for internal triggering, a BNC short circuit is connected to the TRIGGER IN connector. When the pulse generator is connected to TRIGGER IN, move the BNC short to the SWEEP IN 0 to 10V connector. Otherwise, signals on the sweep in line could affect triggering.
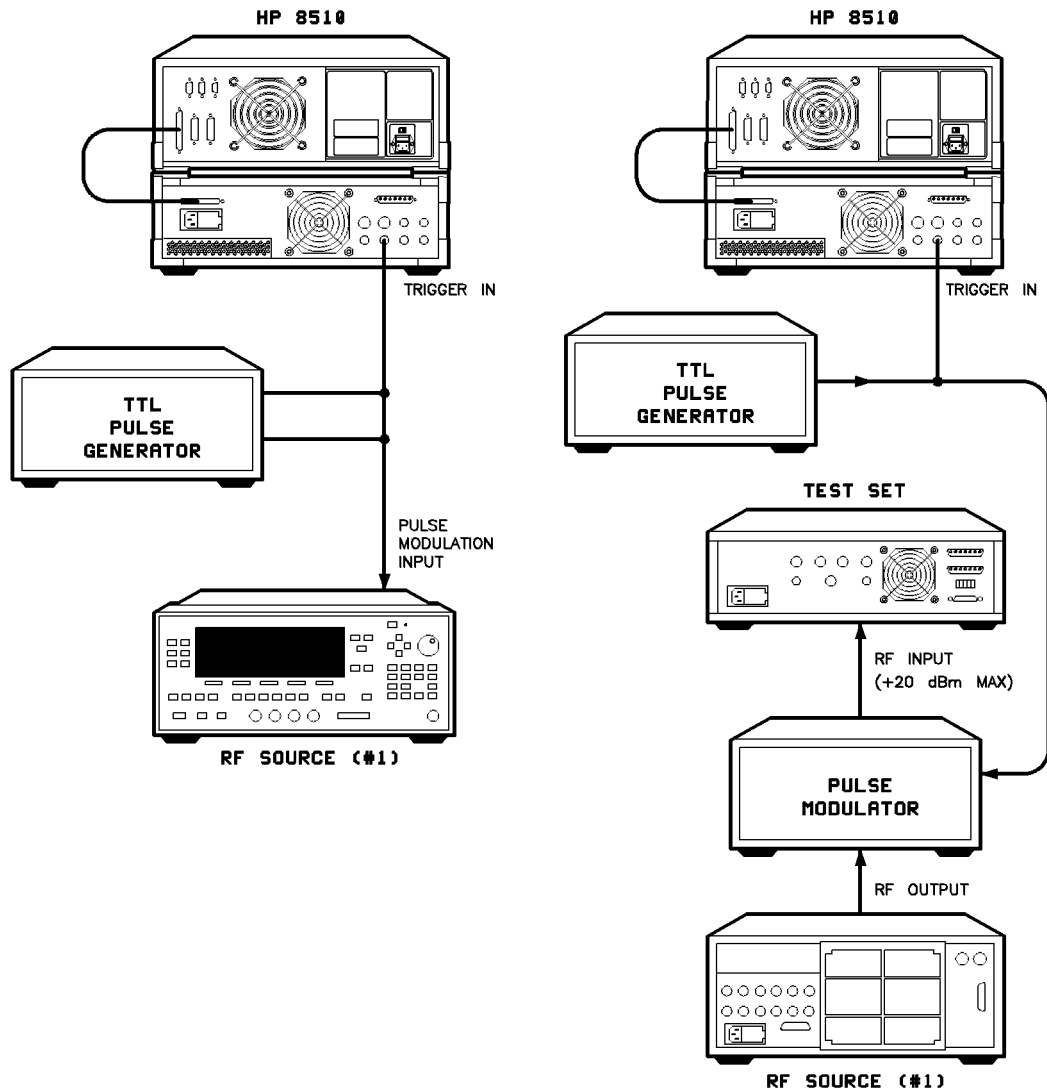
Figure 9-1. External Control of PRP and Duty Cycle

Synchronization is assured because time equals zero seconds for each measurement cycle is defined as the first falling edge of the trigger input after stop sweep is ready (high). Figure 9-1b shows connection of an external pulse modulator instead of the internal modulator in the RF source.

Figure 9-2 shows results using this pulse modulation and triggering method when the pulse modulation input to the RF source is a continuous train of 10 microseconds PRP, 50 percent duty cycle pulses. The same input is applied to TRIGGER IN, and TRIGGERING EXTERNAL is selected.

Figure 9-2.
Using External Trigger and External Modulation PRP = 10 microseconds, Duty Cycle = 50%

Figure 9-2a is the pulse profile domain response. Multiple pulses are visible because the stop time is greater than the stimulus PRP. Notice that for external triggering the minimum start time is about positive 3 measurement resolution periods with respect to the external trigger. Even though the internal pulse output is not used in this particular configuration, the pulse profile measurement resolution period is set by algorithm using the greater of the pulse width and stop time.

Figure 9-2b is the frequency domain response with the trigger delay set to measure during the On time of the pulse.

One method used to set the trigger delay to an appropriate value is:

1. Press (DOMAIN) PULSE PROFILE, then set appropriate Start and Stop times.

2. Press (MARKER), then move the marker to the point on the pulse you want the frequency domain measurement to be made.

3. Press (STIMULUS MENU) MORE TRIGGER MODE TRIGGER DELAY.

   The current value of the trigger delay will be displayed. Now press (=MARKER). The time value at the marker will be assigned to the trigger delay function.

4. Press (DOMAIN) FREQUENCY. The trace shows the response at the time after the TTL Trigger In signal falling edge as set by the trigger delay value.

In your application it may be desirable to complement the pulse modulation and the external trigger signals.

10

High Power Measurements

Signal Level Characteristics

Use Figure 10-1 to examine the maximum power ratings and normal signal levels present in the test set. The signal levels are approximate, with signal path loss increasing with frequency. Note the following characteristics:

- Typically, the RF input is about 9 dBm and the loss to the selected test port is about 9 dB.

- With the step attenuators set to zero dB, the loss from the RF input to the a1 or the a2 mixer, and the loss from Port 1 or Port 2 to the b1 or the b2 mixer, are approximately equal at about 26 dB.

- Since each mixer includes a 20 MHz preamplifier to offset its conversion loss, measurement of the User Parameters will show the IF level to be about 22 dB less than the RF input or the signal level at the test port.

- For specified performance, the maximum IF signal level as measured by the user parameters is -10 dBm. Higher signal levels cause errors due to compression, and lower signal levels produce greater uncertainty due to noise.

Caution　　Components in the test set will be be damaged at certain signal levels. To avoid damage, observe the following operating precautions:

- Use the PORT 1 and PORT 2 attenuators (Stimulus Power menu) to protect the mixer input — the mixer damage level is +20 dBm.

- Install appropriate components in the rear panel extension links to protect the test set Forward/Reverse switch — the damage level is +20 dBm applied at any input or output. This means that if the device output is greater than +20 dBm, the switch can be damaged by +20 dBm present at either LOW POWER OUT connector.

- If the device output is greater than +43 dBm, use appropriate components to protect the test set ports (and the Forward/Reverse switch) — the damage level is +43 dBm (20 watts) applied at PORT 1 or PORT 2 for the HP 85110A, and +47 dBm (50 watts) for the HP 85110L.
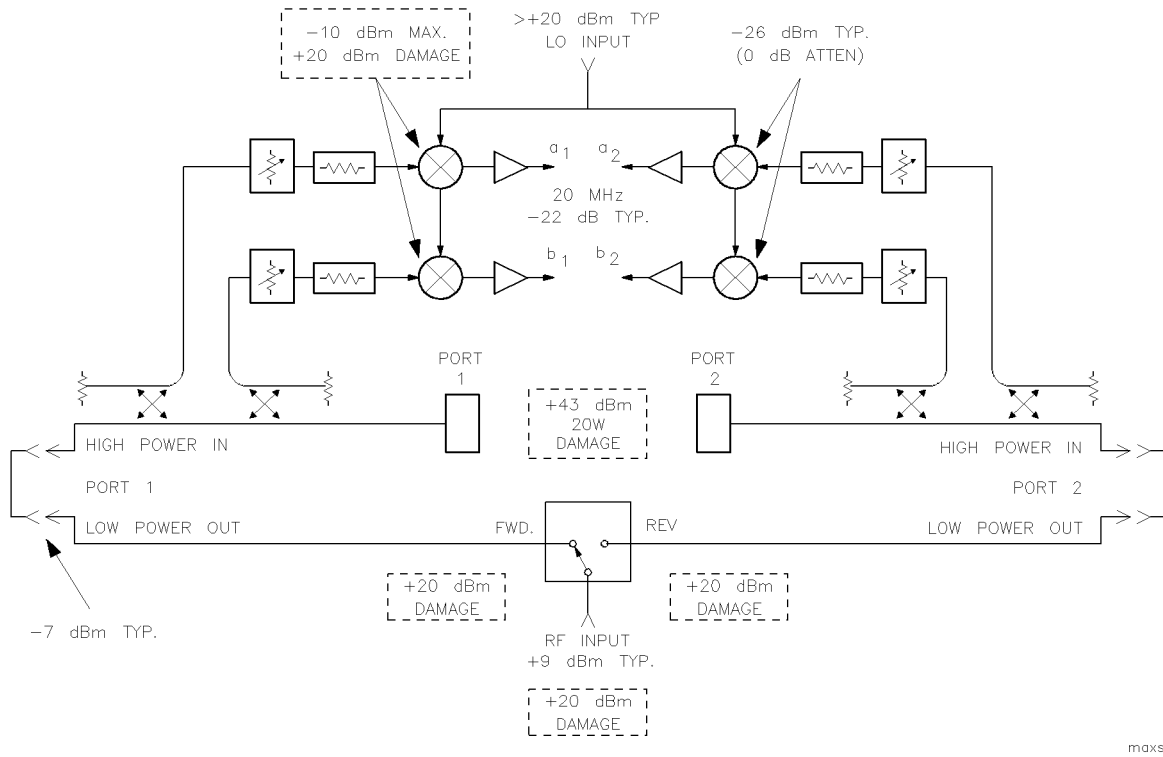
Figure 10-1. Test Set Maximum Signal Levels

Connecting external signal conditioning

The test set rear panel links labeled PORT 1 and PORT 2 can be used to install external equipment in the Port 1 and Port 2 signal paths. The connectors labeled LOW POWER OUT each connect to an output of the forward/reverse switch. The connectors labeled HIGH POWER IN connect to the front panel measurement PORT 1 or PORT 2.

Note the damage levels indicated in Figure 10-1. The maximum power rating of the forward/reverse switch is +20 dBm applied at the RF input, or applied to the forward/reverse poles via either LOW POWER OUT connector. The maximum signal level applied at either HIGH POWER IN connector, or to either of the front panel PORT 1 and PORT 2 connectors is +43 dBm for the HP 85110A, and +47 dBm for the HP 85110L.

Example High Power Measurements

The best procedure for setting signal levels in the test set begins with estimating the input and output power levels of the device under test. When the test set is configured to handle these levels, the operating device is connected and the power estimates are verified by measuring the user parameters. If the estimates were inaccurate, the test set configuration is changed so that power levels at all points in the system are within limits. When this is accomplished, the device is removed, measurement calibration is performed, then the device is installed and its S-parameters are measured. Following are two examples of measurements on high power devices.

Measure a 30 dB Amplifier

Figure 10-2 shows the setup for measurement of an amplifier having about 30 dB of gain. Using the standard RF source power setting of +9 dBm, the signal level at Port 1 is about +0 dBm, the level at the b2 mixer is about +5 dBm, and the signal level at the reverse pole of the forward/reverse switch is about +30 dBm. In order to avoid damage:

■ The ATTENUATOR PORT 2: step attenuator must be set to at least 20 dB to protect the b2 mixer; and,

■ An attenuator or isolator must be added in the rear panel PORT 2 links to reduce the signal level at the reverse pole of the switch to below +20 dBm.

An isolator, providing about 30 dB of isolation between Port 2 and the switch, is the best choice because it can preserve the dynamic range for reverse measurements. Better performance for the reverse measurements will be obtained because the isolator will minimize the insertion loss from the reverse pole of the switch to Port 2, and to a2.
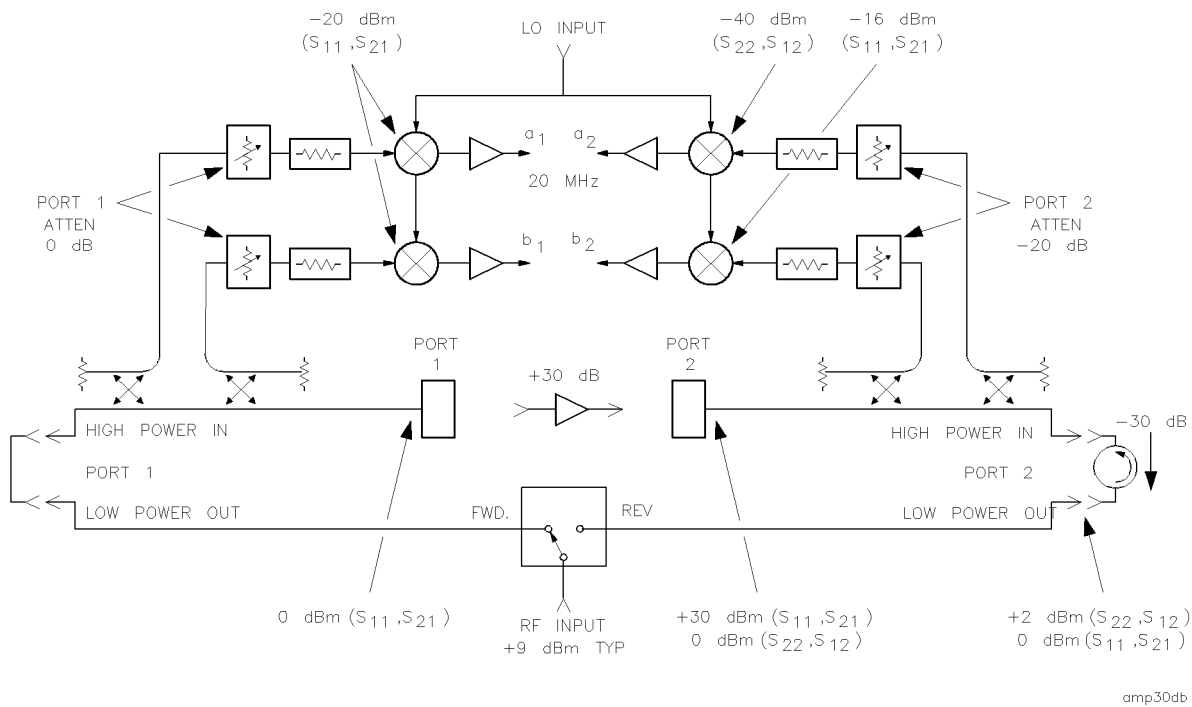
Figure 10-2. Measuring a 30 dB gain Amplifier

Measure an Amplifier with High Input Levels

Figure 10-3 shows the setup for measurement of an amplifier with about 20 dB of gain that needs an input level of about 40 dBm. A 40 dB gain amplifier is installed in the rear panel PORT 1 links to boost the signal level to the desired value without exceeding +43 dBm (20 watts). The signal level at the test port is about +60 dBm, making the signal levels at the a1 mixer and the b1 mixer over +30 dBm. In order to avoid damage:

■ The ATTENUATOR PORT 1: attenuator must be set to 30 dB in order to reduce the a1 and b1 signal levels to below −10 dBm;

■ On the transmission return side, the amplifier output is about 60 dBm, making it necessary to add 20 dB of loss between it and Port 2 in order to reduce the signal level incident at Port 2 to less than +43 dBm for the HP 85110A, and +47 dBm for the HP 85110L;

■ The ATTENUATOR PORT 2: step attenuator must be set to 30 dB in order to protect the b2 mixer; and

■ The reverse pole of the forward/reverse switch must be protected by installing an attenuator or isolator in the rear panel PORT 2 links to reduce the signal level at the reverse pole of the switch to below +20 dBm.

The coupler is used in the transmission return signal path because it provides the necessary loss and will probably provide a more stable signal path than a high power attenuator that would otherwise be required. A high power termination is required to terminate the through arm of the coupler.

Use these examples as a guide for considerations that are special to your test setup.
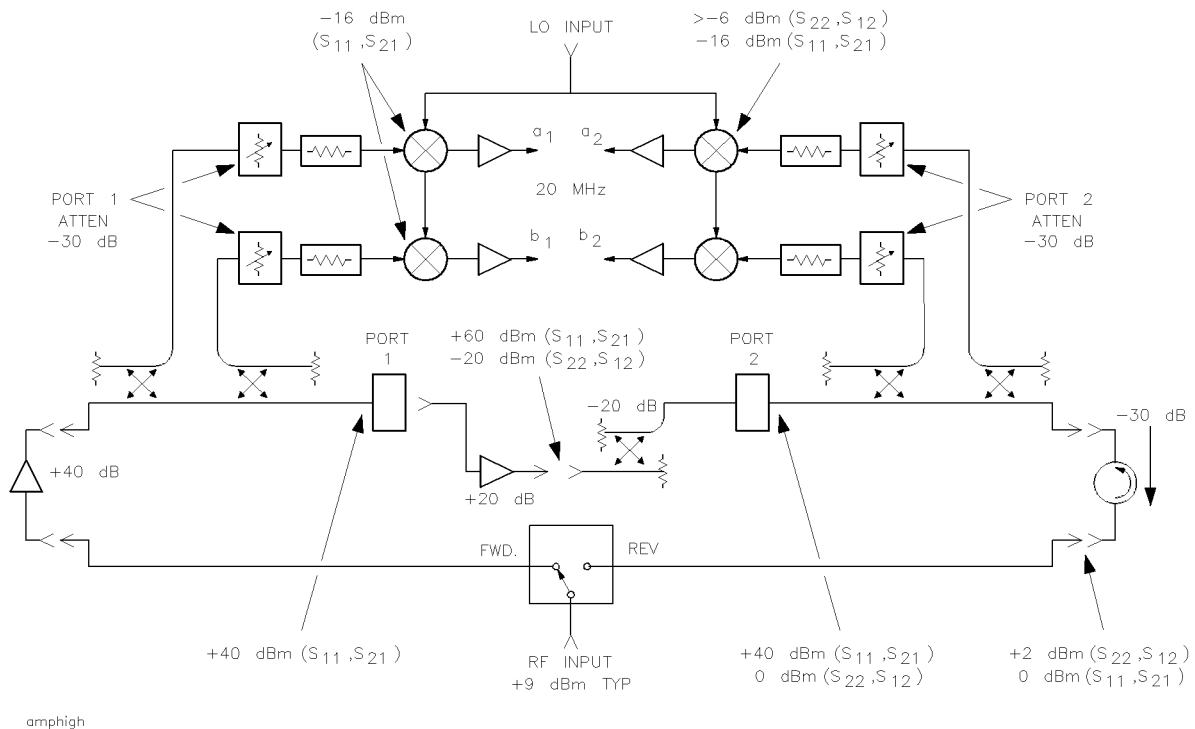
Figure 10-3. Measuring an Amplifier with High Input Levels

Using the Port 1 and Port 2 Attenuators

The Port 1 and Port 2 step attenuators are used to adjust the signal level into the mixers and thus protect the mixers from excessively high signal levels. Note that the attenuators do not change the Port 1 or Port 2 signal levels.

Controlling the Attenuators

Set the step attenuators as follows.

- Press (STIMULUS MENU) POWER MENU ATTENUATOR PORT: 1 or ATTENUATOR PORT: 2 .

Use the knob, STEP keys, or numeric entry to set the attenuator from 0 dB to 90 dB in 10 dB steps. Familiarize yourself with operation of the step attenuators by measuring the user parameters.

Measure User Parameters and Set Attenuators

In order to maintain specified performance, the IF signal levels are less than -10 dBm as measured by the user parameters. Connect an appropriate device at Port 1 or Port 2 for each measurement, turn on a measurement marker, then measure the user parameters in order to verify the IF signal levels as follows.

- Press (PARAMETER MENU) USER 1 a1 and observe the IF signal level in the LOG MAG format.

- Press USER 4 b1 and observe the IF signal level. If either a1 or b1 is greater than -10 dBm at any point in the trace, increase the ATTENUATOR PORT: 1 value.

- Press USER 3 a2 .

- REDEFINE PARAMETER DRIVE DRIVE: PORT 2 .

  Observe the IF signal level.

- Press USER 2 b2 and observe the IF signal level. This shows the level with the signal applied to Port 1. If either a2 or b2 is greater than -10 dBm at any point in the trace, increase the ATTENUATOR PORT: 2 value.

  In some applications it may be necessary to measure the signal at b2 with the signal applied to Port 2. For this measurement:

- Press USER 2 b2 .

- REDEFINE PARAMETER DRIVE DRIVE: PORT 2 .

Observe the IF signal level.

Before calibration, measure these user parameters with the calibration standards, then with the device under test connected and operating.

Generally, set the attenuators to obtain the maximum possible mixer input signal level (less than -10 dBm) with the device connected and operating. This will provide the best signal-to-noise ratio for the measurement. Then remove the device and perform measurement calibration. For best accuracy, do not change either attenuator between calibration and measurement.

Changing Signal Path After Calibration

If any attenuator or other external equipment is changed after calibration, the measurement results cannot be specified except by your own estimation of the error contribution of the change. For example, when the port attenuation is changed with correction On, the CAUTION: CORRECTION MAY BE INVALID is displayed. The operator must judge whether the error is tolerable in the particular application and how to compensate for the change.

The only reason to change the internal attenuators or external equipment between calibration and measurement is to maximize the levels under both conditions, thus minimizing uncertainty due to noise. Many factors will enter into the decision of whether it is more accurate to calibrate at a low signal level without changing the setup, or change the setup to optimize levels for both calibration and measurement. Changing the Port 1 or the Port 2 attenuator does not seriously change the test set mismatch, directivity, or isolation characteristics, but will change the frequency response magnitude and phase. This difference in the frequency response between calibration and measurement can be normalized using the HP 8510 trace memories.

The application question is: Does increasing the signal levels during calibration improve the calibration enough to risk greater error contributions possible by changing the setup?

Set the Attenuators

If only the Port 1 or Port 2 attenuators are changed, the following procedure can minimize the errors.

1. Connect a short or a thru and set the Port 1 and Port 2 attenuators for best IF signal levels during calibration.

2. Perform the appropriate measurement calibration.

3. With an appropriate standard connected, set the Port 1 and Port 2 attenuators to the setting required for operating the test device.

If you view the response of a short circuit, notice that changing the Port 1 attenuators has negligible effect on the S_{11} marker reading, and that changing Port 2 attenuators has negligible effect on the S_{22} marker reading. This is due to the way that the attenuators are paired. Both the reference and the test signal are changed an approximately equal amount.

However, when viewing S_{21} or S_{12}, changing the Port 1 or Port 2 attenuators offsets the marker reading by the difference in the Port 1 and Port 2 values.

Store Trace Memories

The main frequency response effects of changing the attenuators can be compensated for by using the HP 8510 trace memories and trace mathematics as follows.

1. Connect the thru used for calibration. Set the port attenuators to the value used for measurement of the device. Recheck the user parameter levels then press $\boxed{S_{21}}$.

2. Press $\boxed{\text{DISPLAY}}$ DATA →MEMORY to store the S_{21} trace in default trace memory 1. This trace is the frequency response difference of the S_{21} signal path between calibration and measurement.

3. Press $\boxed{\text{S}_{12}}$ $\boxed{\text{DISPLAY}}$ `DATA → MEMORY` to store the S_{12} trace in trace memory 2. This trace is the frequency response difference of the S_{12} signal path between calibration and measurement.

Now that these traces are stored, they can be used to normalize the corrected data.

View the Normalized Parameters

Use these traces to normalize the corrected data to the new levels after the attenuation is changed. This example uses normalization only for S_{21} and S_{12}. Press the following keys to view the corrected parameters.

1. Press $\boxed{\text{DISPLAY}}$ `DISPLAY: DATA`.

2. Press $\boxed{\text{S}_{11}}$ and view the S_{11} measurement.

3. Press $\boxed{\text{S}_{22}}$ and view the S_{22} measurement.

4. Press $\boxed{\text{S}_{21}}$ and view the S_{21} measurement. If the thru is connected, the transmission coefficient should be $1\angle 0°$.

5. Press $\boxed{\text{S}_{12}}$ and view the S_{12} measurement.

View the S_{12} measurement. If the thru is connected, the transmission coefficient should be $1\angle 0°$.

Normalization is turned off for the S_{11} and S_{22} measurements, then the appropriate memory is selected and normalization is turned on to view S_{21} and S_{12}.

Since these are accurate, repeatable attenuators, this sequence may be effective in your application. If it is necessary to change other parts of the test setup, especially components connected to the test ports or connected between the rear panel links, this procedure may require additional steps to adequately compensate for the changes.

Selecting the Appropriate Measurement Calibration

The HP 8510 pulsed-RF network analyzer system allows you to calibrate in the same environment as your measurement. For example, if you are making a high power, pulsed-RF measurement, you can calibrate in the same high power, pulsed-RF mode. Calibration data is taken only while the pulse is on. This type of calibration may prevent damage to calibration standards that would be damaged in high power, CW calibrations.

Signal levels available for calibration and for measurement may also influence the decision of which error model to use for the measurement.

If appropriate signal levels can be achieved for all parameters during calibration and measurement, the HP 8510 2-Port accuracy enhancement error model, either the HP 8510 Full 2-Port or TRL 2-Port, provides best accuracy by providing best characterization and removal of the systematic errors in the test setup. If the device is noninsertable, the HP 8510 Adapter Removal calibration procedure can be implemented using the Full 2-Port and/or the TRL 2-Port calibration.

However, there are applications in which the 2-Port error model cannot be used. There are others in which better results are produced using other calibration techniques described later. These are the reasons that 2-Port correction cannot be used effectively:

1. Very low signal levels of the S_{22} and S_{12} measurement will probably reduce the accuracy of the S_{11} and S_{21} measurements.

   Using 2-Port correction, the values of all four parameters are used to find the corrected value for the displayed parameter. If, for example, the reverse parameters are not representative of their actual values due to insufficient signal levels, then their contribution to the accuracy enhancement algorithm will cause errors. This leads to noisy, nonrepeatable data for the other parameters, even if their measured data is representative.

2. Equipment external to the HP test set must be switched depending upon the parameter being measured.

   There is no means of automatically switching equipment external to the test set depending upon the S-parameter being measured.

   Using 2-Port correction, all four S-parameters are automatically selected in sequence, and there is no signal available to indicate which parameter is being measured. If dynamic range considerations make it necessary to change the test set configuration for measurement of different parameters, the automatic switching used in the 2-Port error model cannot be used.

3. Test set configuration changes error terms other than frequency response between calibration and measurement.

   If changes to the test set between calibration and measurement significantly change the directivity, isolation, source or load match, or frequency response error coefficients measured during the calibration, then the corrected data will be in error. If only the frequency response characteristics of the test set change, compensation can be provided using the display memory features of the HP 8510B. (See the Changing Signal Path After Calibration section in this chapter.)

   In all of these situations the best choice will be to use a separate error model for each parameter. For example, use the Response or the Response & Isolation calibration for the S_{21} and S_{12} parameters, and 1-Port calibrations for the S_{11} and S_{22} parameters. Combining error models like this allows setup, calibration, and measurement for each parameter to be accomplished independently. After separate calibration for each parameter, the forward/reverse switch in the test set will respond to front panel parameter selections, and the cal set for the selected parameter will be recalled.

   Combining error models is described in the HP 8510 Operating and Programming manual, Basic Network Measurements portion, with the Cal menu in the S-Parameter Test Set Calibration Error Models section.

General Calibration and Measurement Sequence

- Specify device input/output requirements.

- Configure test set for these levels, plus guardband.

- Connect operating device and verify levels.

- Adjust levels for best dynamic range.

- Perform measurement calibration.

- Measure operating device S-parameters.

General Calibration and Measurement Sequence Using Display Math

- Specify device input/output requirements.

- Configure test set for these levels, plus guardband.

- Connect operating device and verify levels.

- Configure setup for best dynamic range.

- Connect standards and verify levels.

- Change setup for best dynamic range during calibration.

- Perform measurement calibration.|(Before saving cal set, configure setup for operating device.)

- Connect appropriate standards and store reference traces.

- Connect operating device.

- Use normalization to view device parameters.

Reference Data

Creating Pulse Hardware State and Instrument State Files

If the HP pulsed-RF system tape is not available, create the necessary files as follows.

Network Analyzer System Bus	HP-IB Addresses
8510	16
System Bus	17
Source #1	19 (RF)
Test Set	20
Plotter	05
Printer	01
Disc	00
Source #2	18 (LO)
PASS-THRU	31
RF Switch	31

1. Press (PRESET) to set the instrument to a known state.

2. Set system bus HP-IB addresses of sources:

   (SYSTEM) HP-IB ADDRESSES

   SOURCE #1 1 9 x1

   SOURCE #2 1 8 x1 .

3. Set sweep mode.

   Press (STIMULUS MENU) STEP .

4. Multiple source control.

   Edit the Multiple Source configuration to set the LO source 20 MHz above the test source and tune the receiver to 20 MHz as follows:

   (SYSTEM) MORE EDIT MULT. SRC.

   DEFINE SOURCE 1 MULTIPLIER NUMER x1 MULTIPLIER DENOM. x1
   OFFSET FREQUENCY 0 x1 DONE

DEFINE SOURCE 2 MULTIPLIER NUMER. x1 MULTIPLIER DENOM. x1
OFFSET FREQUENCY 2 0 M/μ DONE

DEFINE RECEIVER CONSTANT FREQUENCY 2 0 M/μ DONE

MULT. SRC. ON/SAVE

M annotation appears.

Other settings for pulsed-RF operation are as follows:

[SYSTEM] MORE PULSE CONFIG DETECTOR: WIDE BW

W annotation appears.

PULSE OUT: HIGH or PULSE OUT: LOW (depending on pulse modulator; HIGH for 834x
test signal source)

[SYSTEM] MORE SYSTEM PHASELOCK NONE

[SYSTEM] MORE POWER LEVELING SOURCE 1: INTERNAL SOURCE 2: EXT. LEVEL .

[STIMULUS] MORE POWER MENU POWER SOURCE 1 [9] [x1] POWER SOURCE 2 [–] [1] [0] [x1] .

5. Finally, [SAVE] INST. STATE (POWER UP) 8 .

Store the instrument state file and hardware state file on tape/disc as follows:

■ Store the pulse hardware state.

[TAPE/DISC] STORAGE IS TAPE STORE MORE HARDWARE STATE FILE 8 .

■ Store pulse instrument state from Inst. State 8.

[STORE] INST. STATE 1-8 INST. STATE (POWER UP) 8 FILE 8 .

In order to restore a known instrument state, you can [RECALL] INST. STATE 8 .

Pulse Menus

Several new menus have been created to support the pulse applications. These appear in the
DOMAIN, STIMULUS, and SYSTEM menu structures.

Pulse Configuration Menu

The new Pulse Configuration menu is reached by pressing [SYSTEM] MORE PULSE CONFIG .

DETECTOR: WIDE BW

Selects the wide bandwidth IF path and detectors. Must first be selected manually for
Frequency domain (Preset selects Normal BW); always selected automatically for Pulse Profile
domain.

DETECTOR: NORMAL BW

Selects the precision 10 kHz IF path and detectors (Preset).

PULSE WIDTH

Sets the width of the pulse from the HP 8510 rear panel. PULSE OUTPUT connector. Range: −6 res. periods to 40.88 ms; Preset 10 μs.

DUTY CYCLE

For internal triggering, sets the maximum allowed duty cycle. Range: 0 to 100 percent. Preset 10 percent.

PULSE OUT: HIGH

Selects the polarity of the TTL Pulse Output to High for the On period of the pulse (Preset).

PULSE OUT: LOW

Selects the polarity of the TTL Pulse Output to Low for the On period of the pulse.

Trigger Mode Menu. The new Trigger Mode menu is reached by pressing STIMULUS, MORE, TRIGGER MODE.

TRIGGER DELAY

Active only in the Frequency domain, used to set the delay between the internal or external measurement trigger and the actual measurement. Range: 0 s to 40.88 ms; Preset 5 μs.

TRIG MODE: INTERNAL

Selects the internal measurement trigger (Preset).

TRIG MODE: EXTERNAL

Selects the falling edge of the TTL signal input at the HP 8510 rear panel TRIGGER IN as the measurement trigger.

HP 8510 Option 008 Added Programming Codes

Following is the list of programming codes added for Option 008.

HP 8510 Option 008 Added Programming Codes

Programming Code	Description
DETENORB; DETEWIDB;	Select Precision Detector (10 kHz bandwidth) Select Wide Bandwidth Detector (1.5 MHz). Selected automatically for PULP;.
DUTC [value];	Set duty cycle limit percent maximum. (Actual duty cycle can be less.)
EXTTOFF; EXTTPOIN;	Select Internal measurement trigger. Select External measurement trigger.
PULOHIGH; PULOLOW;	Select Pulse Output active high. Select Pulse Output active low.
PULP;	PULSE PROFILE. Select Pulse Profile domain.
PULW [value(time suffix)];	Set Pulse Output pulse width. Automatically sets pulse profile sample resolution to 100 ns, 200 ns, 1 μs, or 10 μs; pulse profile minimum span, and minimum start time.
TRID [value(time suffix)];	Set measurement trigger delay.

HP 8510 Option 008 Added Query Commands

Following are the Query commands added for option 008.

HP 8510 Option 008 Added Query Commands

DETE?;	Detector Bandwidth
PULO?;	Pulse Output
EXTT?;	Measurement Trigger mode
DOMA?;	Domain

Domain Menu

FREQUENCY	FREQ
TIME LOW PASS	TIML
TIME BAND PASS	TIMB
AUX. VOLT OUTPUT	AUXV
POWER	POWD
SPECIFY TIME	
SPECIFY GATE	

DOMAIN

Stimulus

MENU

MORE

Stimulus More Menu

HOLD

SINGLE

NUMBER of GROUPS

CONTINUAL

TRIGGER MODE

EDIT LIST

COUPLED CHANNELS

UNCOUPLED CHANNELS

Trigger Mode Menu

TRIGGER DELAY	TRID
TRIGGERING INTERNAL	EXTTOFF
EXTERNAL	EXTTPOIN

SYSTEM

MORE

System More Menu

PULSE CONFIG

EDIT MULT. SRC.

SYSTEM PHASELOCK

POWER LEVELING

ANALOG OUT ON

OFF

SERVICE FUNCTIONS

Pulse Configuration Menu

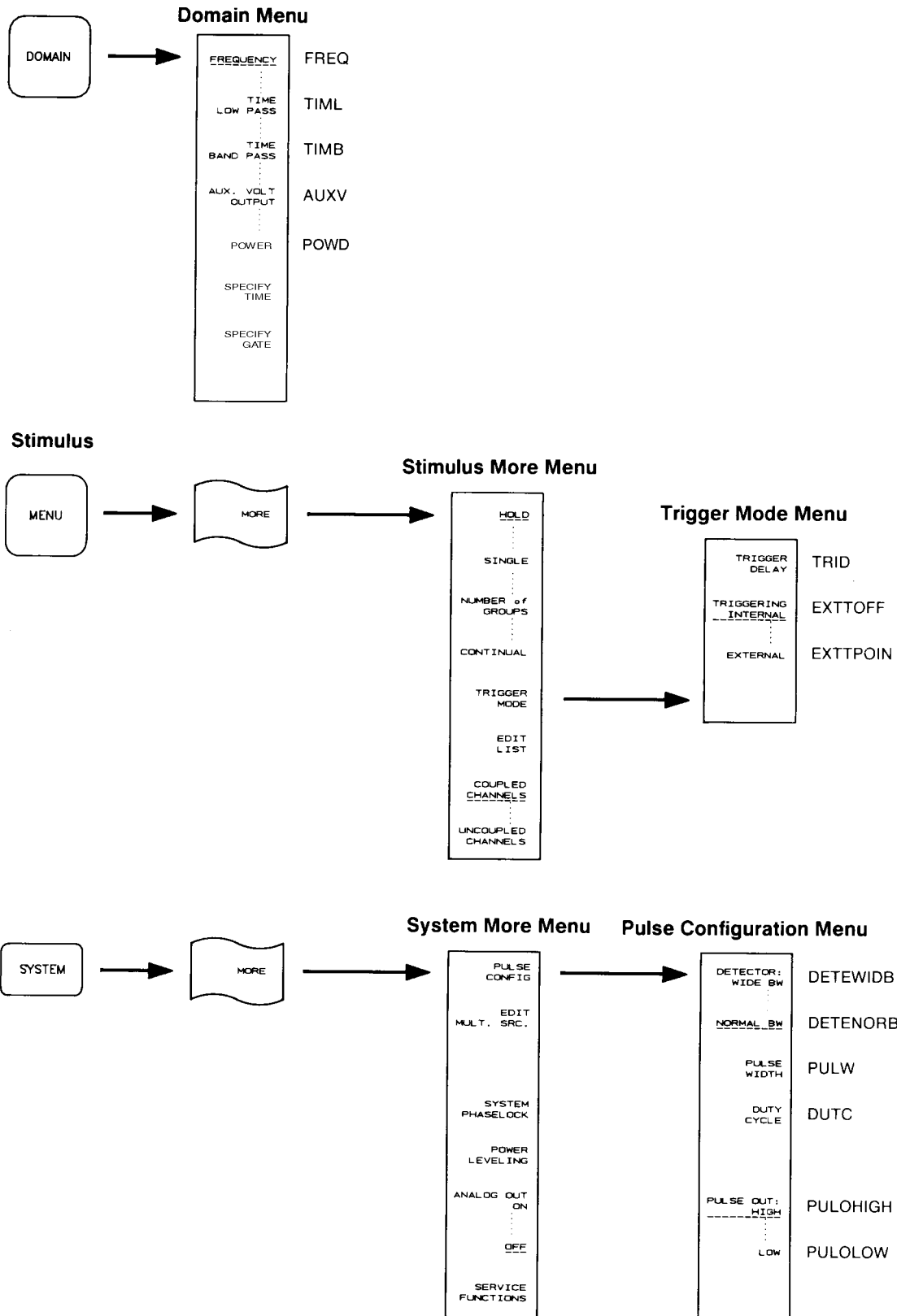|	
DETECTOR: WIDE BW	DETEWIDB
NORMAL BW	DETENORB
PULSE WIDTH	PULW
DUTY CYCLE	DUTC
PULSE OUT: HIGH	PULOHIGH
LOW	PULOLOW

Figure 11-1. Option 008 Domain, Stimulus, and System Menus