Errata

Document Title: Stripline Component Measurements With the 8410A Network Analyzer (AN 117-2)

Part Number: 5952-1000

Revision Date: January 1971

HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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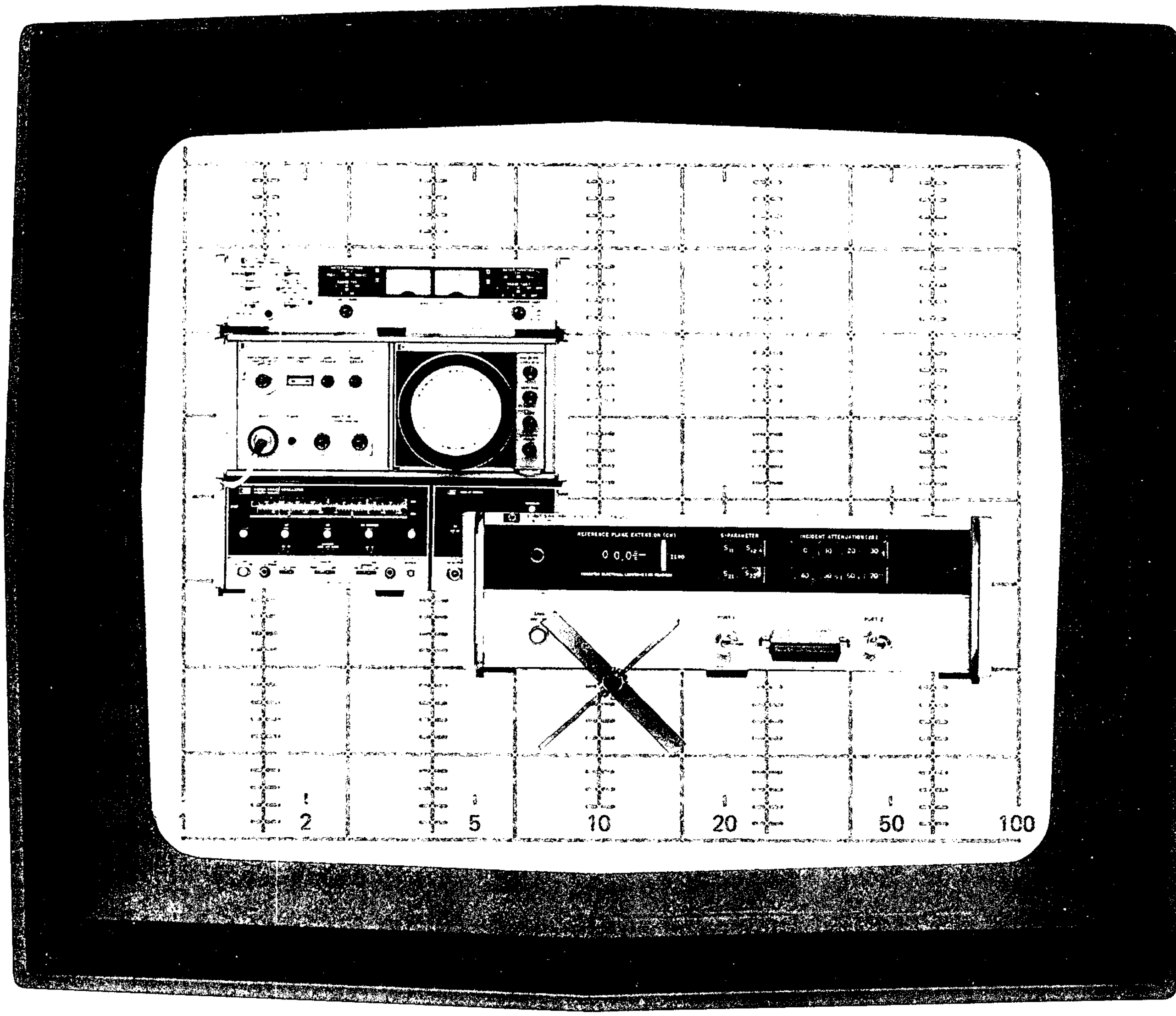
HP AN 117-2

APPLICATION NOTE 117-2

Stripline Component Measurements with the 8410A Network Analyzer



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APPLICATION NOTE 117-2

STRIPLINE COMPONENT MEASUREMENTS WITH THE 8410A NETWORK ANALYZER

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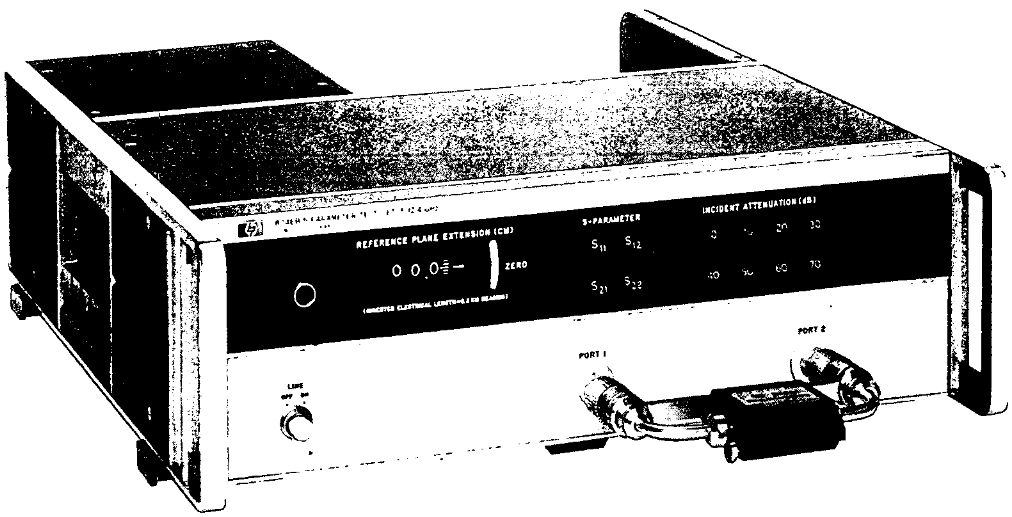
Printed JANUARY 1971



The 8746B S-Parameter Test Set and 11608A Transistor Fixture

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INTRODUCTION

Application Note 117-2 is the second in a series of Hewlett-Packard publications describing the applications and operating techniques of the 8410A Network Analyzer.

The 8410A provides the basic means for measuring the amplitude and phase response of active and passive devices in 50 ohm transmission line or waveguide, over the frequency range from 0.1 to 12.4 GHz.

A continuing development program has made available a series of Test Units and Test Fixtures which allow the network analyzer to be used to characterize a large variety of networks and components quickly, accurately, and conveniently.

Figure 1 shows the 8410A Network Analyzer and the peripheral equipment available. The immediate advantage of such a modular concept, is that only those components necessary to cover a particular frequency range or measure a particular type of device need be purchased with additional units available to expand the measurement capability as and when required.

The earlier publication, Application Note 117-1 describes the basic principles of network analysis and the use of the S-Parameter notation and provides operating instructions for all of the 8410A system components (shown in Figure 1) except the 8746B S-Parameter Test Set and the 11608A Transistor Fixture. The use of these instruments is described here.

The Importance of Network Analysis at Microwave Frequencies

One of the major tasks facing the designer of multi-component circuits is predicting the performance of the final circuit from a knowledge of the parameters of individual components. The engineer responsible for production of each circuit requires almost the opposite information. He must know the tolerances allowable on individual components to ensure a finished product within the specification.

At low operating frequencies, typical operating parameters for a device are usually sufficient to meet the above requirements and the tolerance on phase measurements is not critical. As operating frequencies increase, the phase information becomes more and more important and typical operating parameters are not always sufficient to achieve optimum final performance, particularly when active elements are cascaded.

The obvious solution to such problems is to completely characterize the individual components and thus narrow the limits of uncertainty. Further improvement may then be obtained by selecting components which, when connected together, will complement one another.

Two things are, therefore, required. Firstly, a convenient way of specifying the performance of a device and, secondly, some method of easily and accurately measuring this performance.

It may be shown theoretically that any two-port device such as a transistor, operating under linear conditions, can be completely

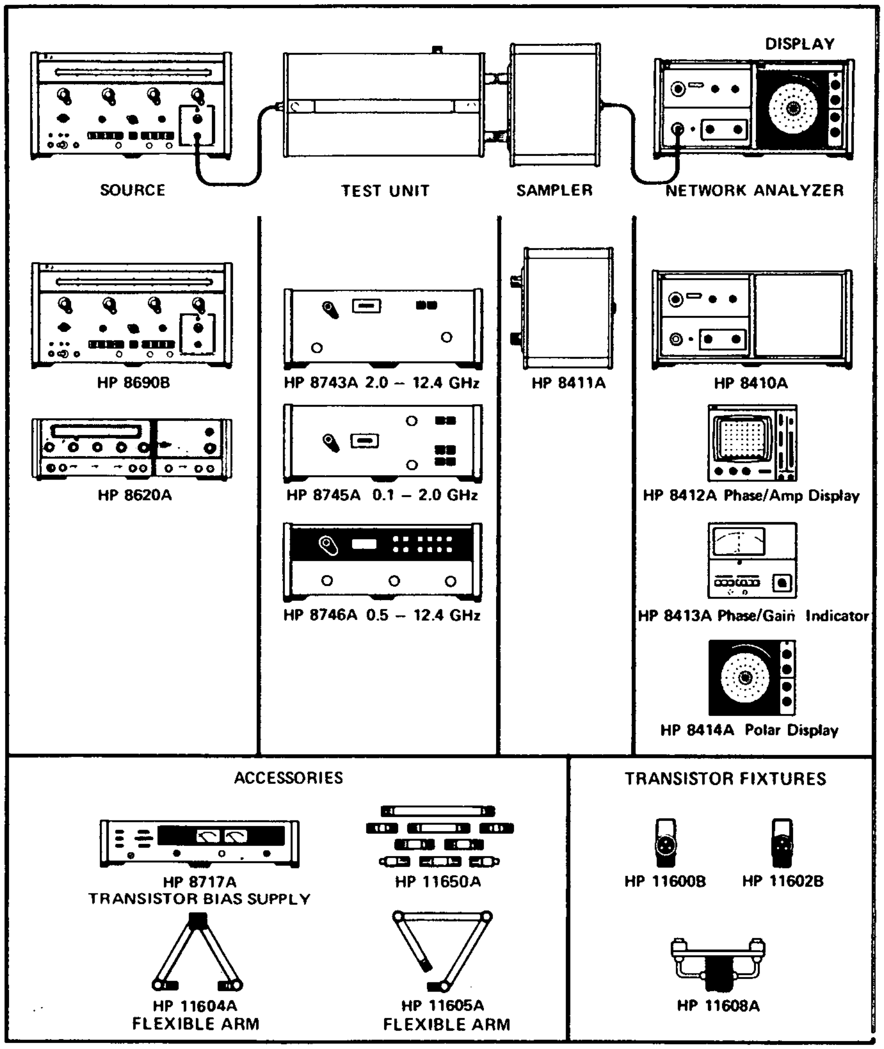


Figure 1. Network Analyzer System Components

specified (at each frequency) by four complex parameters. Several such sets of parameters have been formulated, and each has its own points of merit. H, Y and Z parameters have long been used for characterizing low frequency components and theoretically can be used at microwave frequencies. However, these parameters are difficult to measure at microwave frequencies because they relate to voltage and current measurements under open and short circuit load conditions.

The "scattering parameters" (S-parameters), *offer a more convenient notation at high frequencies, because they relate to the complex reflection and transmission coefficients of a device which is loaded with a characteristic impedance. Mathematically, S-parameters may be manipulated in the same way as other parameters and, if necessary, converted to another form.

Once the S-parameter notation has been accepted, the Network Analyzer System provides a rapid accurate means of direct measurement.

*A More detailed account of the S-Parameter concept and the relation to H, Y and Z parameters will be found in Hewlett-Packard Application Notes 77-1 and 95.

The 8745A S-Parameter Test Set and the 11600B and 11602B Transistor Fixtures (shown in Figure 1) allow wire leaded transistors with a TO-18, TO-72, TO-5, or TO-12 configuration to be directly characterized up to a frequency of 2 GHz. However, solid state technology has extended operating frequencies to well above 2 GHz and the standard wire leaded packages, already inefficient, have become impractical to use. New, low-loss packaging designs that can be incorporated into printed circuit strip transmission lines are gaining wide acceptance and the measurement of such components requires a test fixture with a suitable strip-line configuration and a test unit which covers the appropriate frequency range.

The 8746B S-Parameter Test Set and 11608A Transistor Fixture have been designed for use with the 8410A Network Analyzer to provide direct measurements of stripline components in terms of S-parameter values.

Stripline transistors are the obvious candidates for such measurements, but with the necessary modifications, the 11608A Fixture will also accept other stripline components, such as disc capacitors and resistors or even complete subassemblies.

The 8746B test unit may also be used independently of the 11608A to measure large components and assemblies.

CHAPTER I
THE 8746B S-PARAMETER TEST SET

OPERATING PRINCIPLES

The 8746B test unit operates within the frequency range from 0.5 to 12.4 GHz and has been optimized for use with the 11608A Transistor Fixture. Figure 2 shows both units.

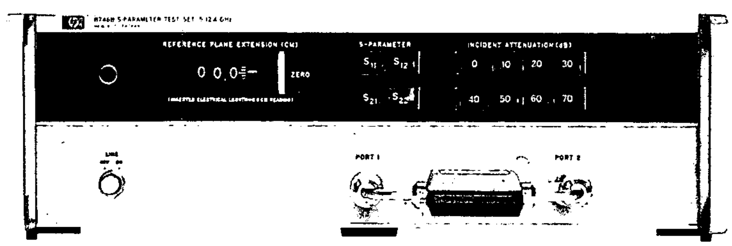


Figure 2. The 8746B S-Parameter Test Set and 11608A Transistor Fixture

Figure 3 shows the configuration of the complete network analyzer system of which the 8746B forms a part and Figure 4 shows a simplified block diagram of the unit.

RF power from the sweep oscillator enters the 8746B through a rear panel connector and is split by a directional coupler to provide a reference signal and a test signal. The test signal passes through a programmable attenuator which may be set to any multiple of 10 dB up to 70 dB by depressing the corresponding front panel pushbutton. This attenuator, therefore, allows the power incident on the test device to be set to a level which ensures linear operation without affecting the reference channel and hence the operation of the Network Analyzer..

After attenuation, the test signal may be switched to either Port 1 for the measurement of forward parameters (S_{11} and S_{21}), or to Port 2 for reverse parameters (S_{12} and S_{22}). A second group of switches determines the return path from the test device for either reflection (S_{11} and S_{22}) or transmission (S_{12} and S_{21}) measurements, and routes the return signal to the TEST channel of the 8411A Sampler.

The correct switch configuration is selected automatically, by depressing the appropriate S-parameter pushbutton on the front panel.

To measure the phase response of the device under test, the 8410A measures the phase difference between the test channel signal and the

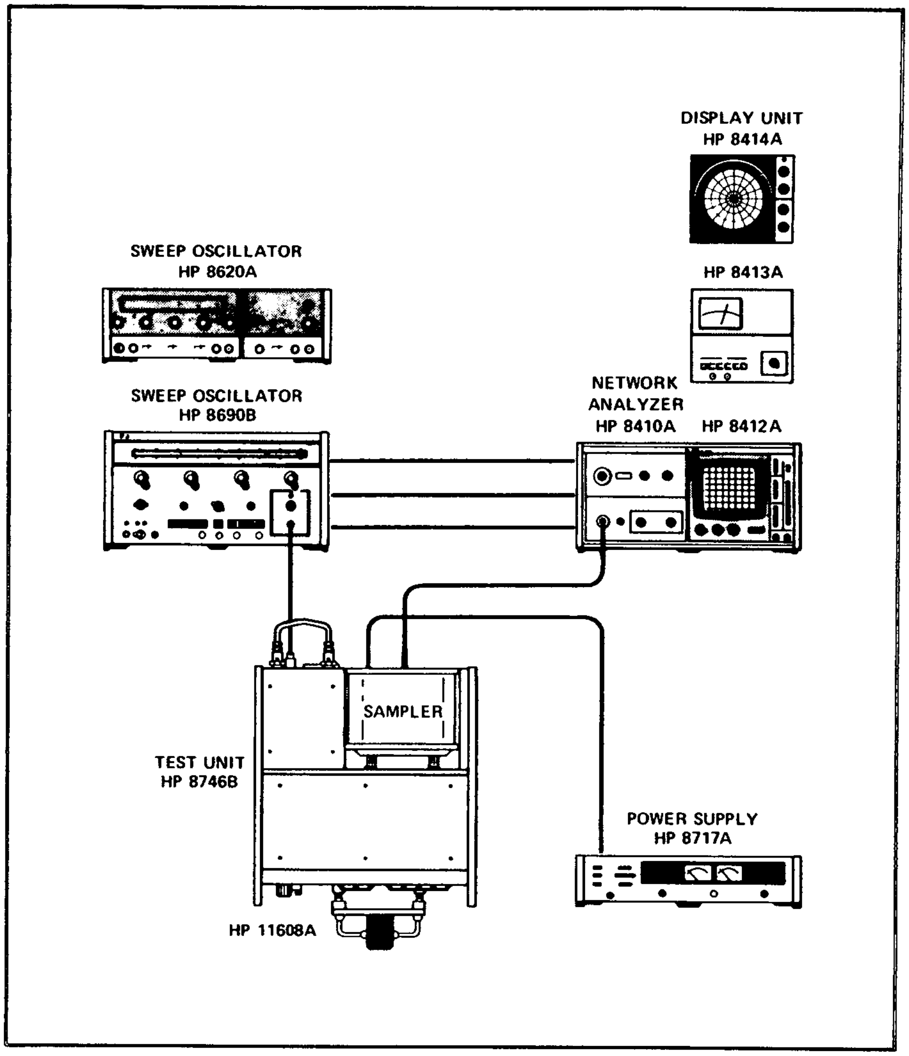


Figure 3. System Configuration for Stripline Measurements

reference channel signal. In order to obtain a swept frequency display of phase angle, therefore, the path length of the two channels must be equalized. To allow for this, the reference signal in the 8746B test unit passes through two adjustable lengths of transmission line, one adjustable continuously, the other in fixed steps. The line stretcher is adjusted by rotating the REFERENCE PLANE EXTENSION control on the front panel, and allows a continuous adjustment of up to 30 cm in the reference channel path length. The front panel digital indicator records half the change in path length and may be independently set to zero (or any other value between 00.0 and 15.0 cm) to provide a reference point.

For some applications, where the electrical length of the external circuit is large, the 30 cm variation provided by the line stretcher will be insufficient.

The EXTERNAL REFERENCE CHANNEL LINK is a U-shaped section of semi-rigid coaxial line attached to the rear panel of the 8746B via two APC-7 connectors. By changing this link, any test channel path length may be compensated.

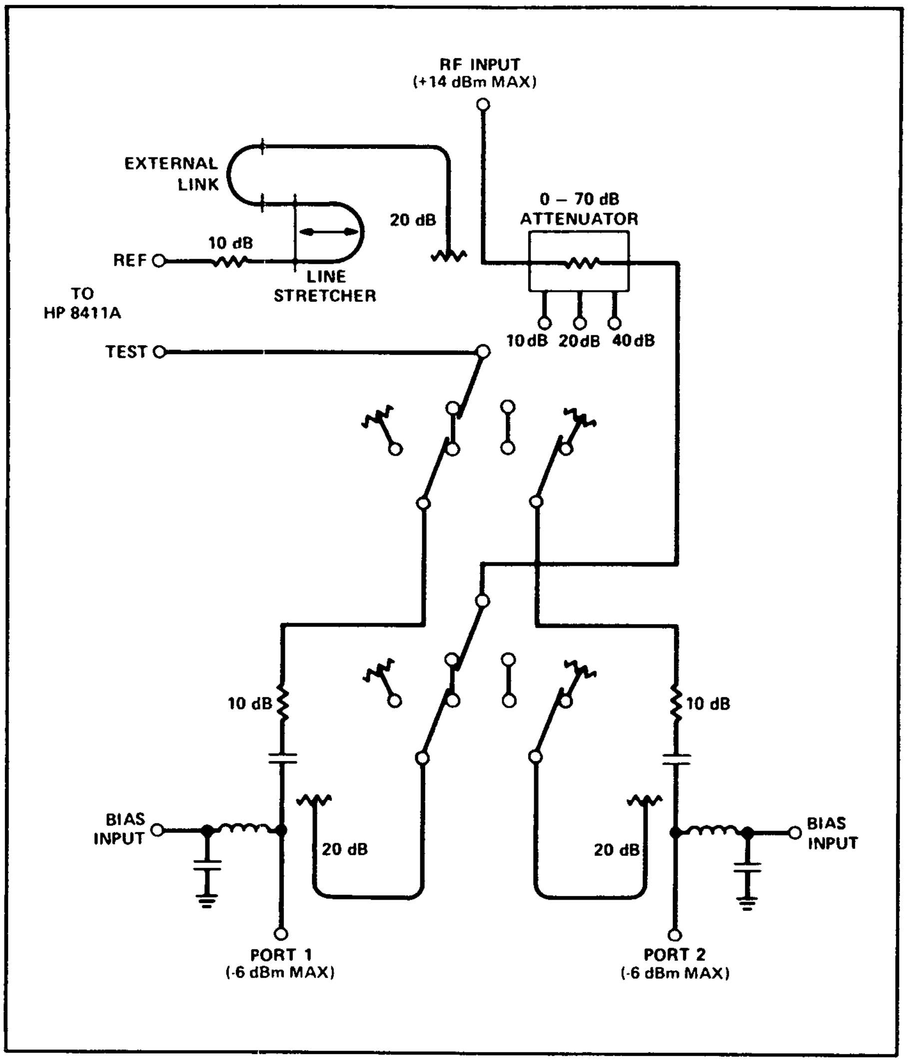


Figure 4. Simplified Block Diagram of the 8746B

The reference channel link supplied with the 8746B is correct for use with the 11608A Transistor Fixture and two further lengths are available for the measurement situations described in Chapter VI.

The REFERENCE PLANE EXTENSION control also allows the phase reference plane to be moved by a known amount. This facility is particularly useful when making measurements of reflection coefficient (S_{11} or S_{22}), for determining the conjugate impedance required at a given point in the line to match the input or output impedance of the device. When measuring transmission parameters (S_{12} or S_{21}), the phase change caused by the physical length of the test device may be compensated, allowing the phase change caused by the active element to be measured.

All reference and test channel connections and the Port 1 and Port 2 connections are made through APC-7 precision 7 mm connectors to ensure maximum repeatability up to 12.4 GHz.

REMOTE CONTROL

The four S-parameters and any value of attenuation may be set by remote control by applying a contact closure or transistor switch to the appropriate pins of a 36-pin connector mounted on the rear panel of the 8746B. Remote control contact closure will also lock-out the front panel pushbuttons to prevent interference with remote operation. A rear panel slide switch allows the attenuator to remain under manual control if required.

The remote control facility makes the 8746B suitable for use with automated or programmable test systems such as the Hewlett-Packard 8542A Automatic Network Analyzer. The facilities provided by such a system are described in Chapter VII.

BIAS FEED

An active test device usually requires DC Bias and the appropriate voltages may be supplied through the 36-pin connector. Bias insertion networks inside the 8746B test unit provide RF isolation of the DC path and feed the bias to the device via the center conductors of Port 1 and Port 2.

Details of the bias supplies required and their use may be found in Chapter III.

8746B OPTIONAL MODIFICATIONS

The standard 8746B test unit (Figure 4) has been designed to provide optimum performance for the measurement of small signal parameters.

The maximum power level which may be applied to the RF input is +14 dBm. This level will provide a -16 dBm (maximum allowable) signal to the reference channel and a -6 dBm incident signal to the test device with the attenuator set to 0 dB. These conditions will provide a dynamic range of 60 dB. If the incident signal level is reduced by using the attenuator, the dynamic range will be reduced accordingly.

To allow measurements to be made with incident signal levels higher than -6 dBm, two modified forms of the 8746B test unit are available. Figure 5 shows simplified block diagrams of the two options.

One modified version (Option 001) increases the available incident power to +4 dBm with a reference channel level of -16 dBm and an RF input level of +14 dBm. This unit could, therefore, allow a test device to operate under non-linear conditions.

By using the attenuator, small signal conditions can also be achieved, but the dynamic range is reduced by 10 dB compared to the standard unit operating at the same incident signal level.

The second modified version (Option 002), increases the maximum incident signal level to approximately +14 dBm at the expense of a seriously degraded mismatch looking back into the two test ports. Consequently, this version is primarily intended for use with an automatic system, where a correction can be applied to the measured parameters to compensate for the higher mismatches.

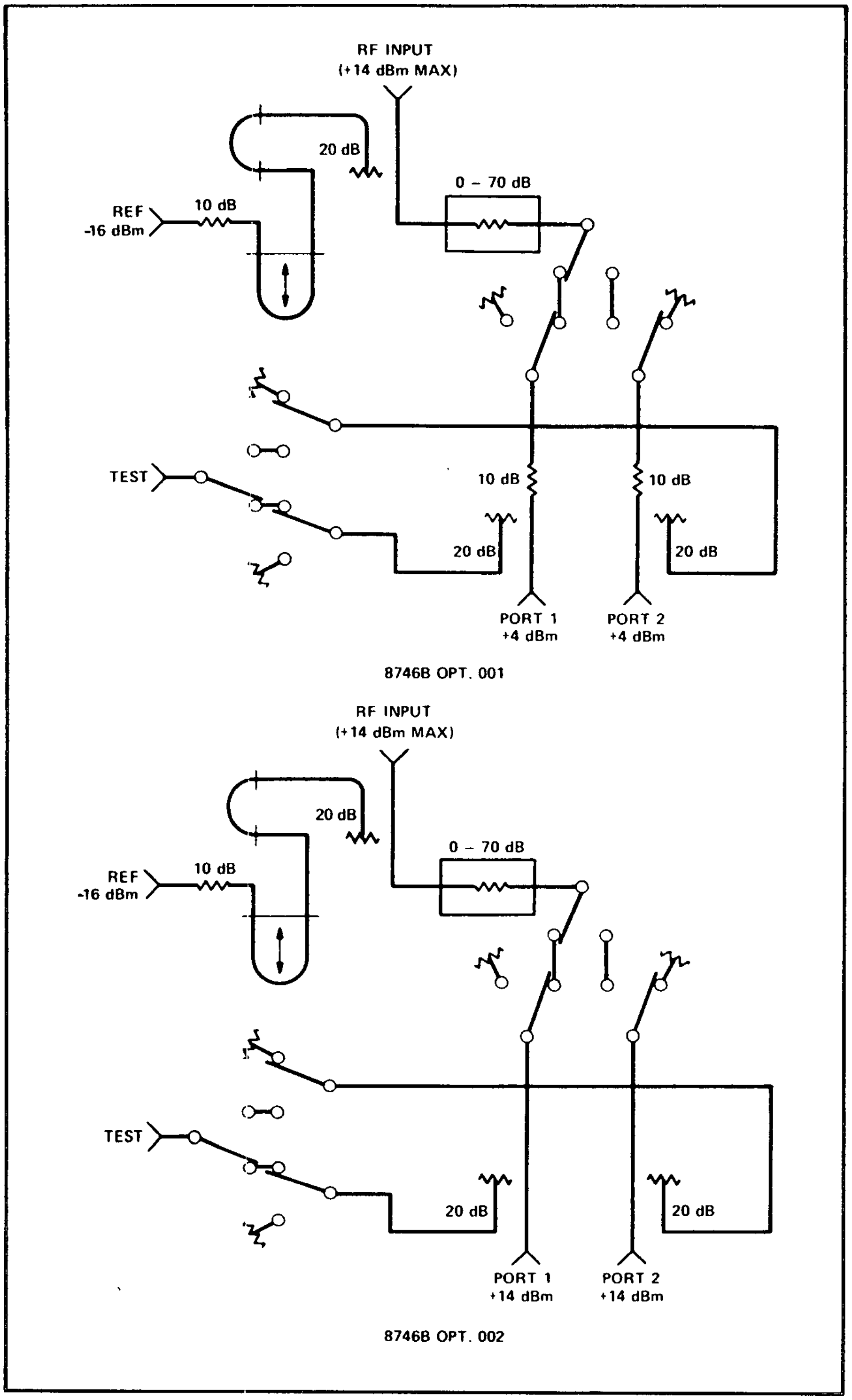


Figure 5. Simplified Block Diagram of Options 001 and 002

CHAPTER II
THE 11608A TRANSISTOR FIXTURE

Stripline devices operate at high frequencies and, therefore, any test fixture designed to accept them must provide a good electrical environment over a broad range of frequencies, which closely resembles the actual operating conditions of the device. This means that the connections between the device leads and the input and output ports of the fixture, must show a low VSWR and low loss and any field perturbation caused by the clamping structure and outer casing must be correctly compensated.

To optimize these conditions for each of the many different package styles with a single fixture design, would not be possible and therefore, for maximum accuracy, the fixture must be tailored to a particular package style.

OPTIONS

The 11608A Transistor Fixture is currently available to accommodate the TI-line package (Option 002) and the K-Disc package (Option 003) with the dimensions given in Figure 6. Other dedicated versions are possible.

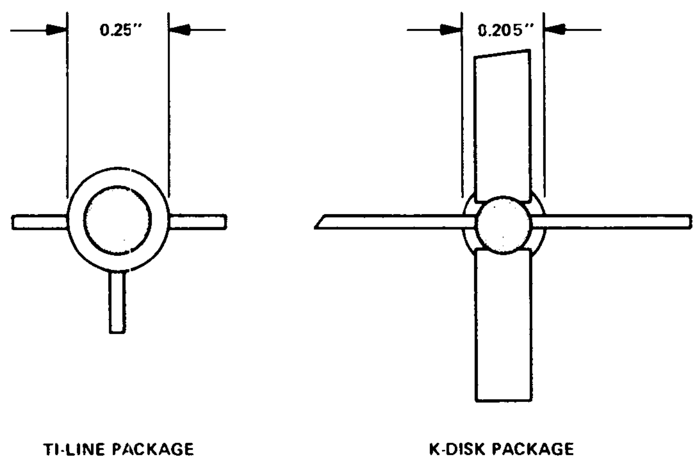


Figure 6. TI-Line and K-Disc Package Styles

To meet the present needs of those who do not use the TI-line or K-Disc package, or have experimental components which require testing, Option 001 is available. This option provides the basic external requirements of Options 002 and 003, but the internal structure has been left blank so that it may be machined and modified, by the user, to suit a particular device.

Detailed machining instructions and tolerances are supplied with the 11608A Option 001 in the form of Hewlett-Packard Operating Note 11608A and an outline of limitations and basic requirements may be found in Chapter V of this application note.

FIXTURE DESIGN

When the transistor fixture is used with the 8746B test unit, the input and output ports mate directly and Port 1 is defined as the input port. The fixture is completely symmetrical and when used with an 8746B test unit with the standard Reference Channel link (Part No. 11604-20021), all path lengths are correctly compensated.

Figure 7 shows the 11608A Test Fixture in detailed and Figure 8 shows parts of the internal structure for each of the three options. With Option 001, the microstrip plate and ground structure are removable so that they may be separately machined. With the dedicated versions, they form a permanent part of the fixture and are not intended to be removed.

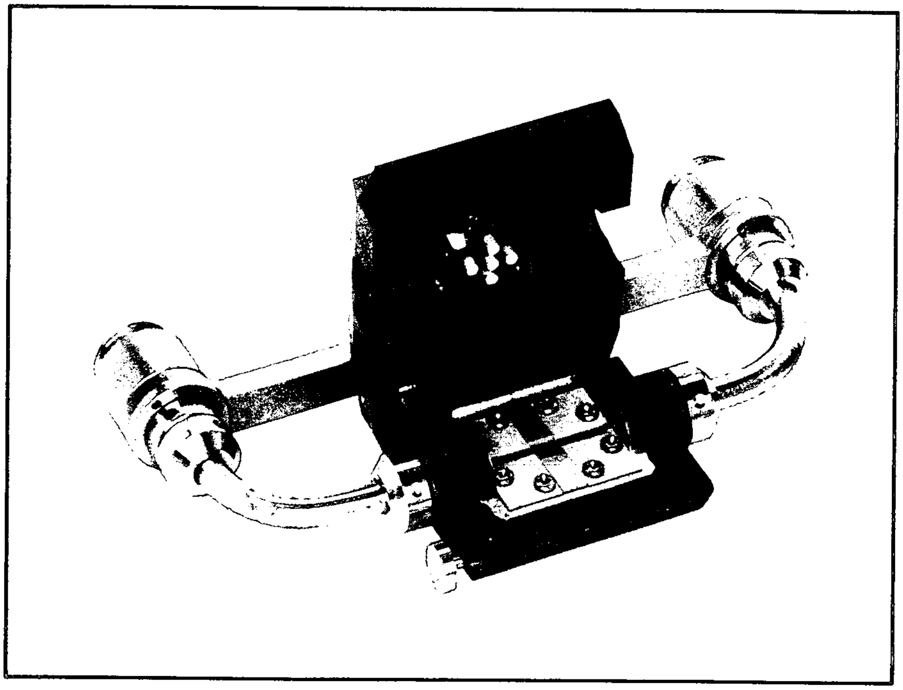


Figure 7. The 11608A Transistor Fixture

A hinged lid with silicone rubber pressure pads, allows the device to be quickly inserted or removed. The five individually mounted pads apply pressure to the main body of the device and to each of the leads, ensuring good electrical contact to the gold plated conductors. The effect of the clamping structure is compensated for the particular package and the lid is lined with lossy material to suppress the propagation of spurious modes.

The complete fixture provides the optimum conditions to ensure maximum measurement accuracy.

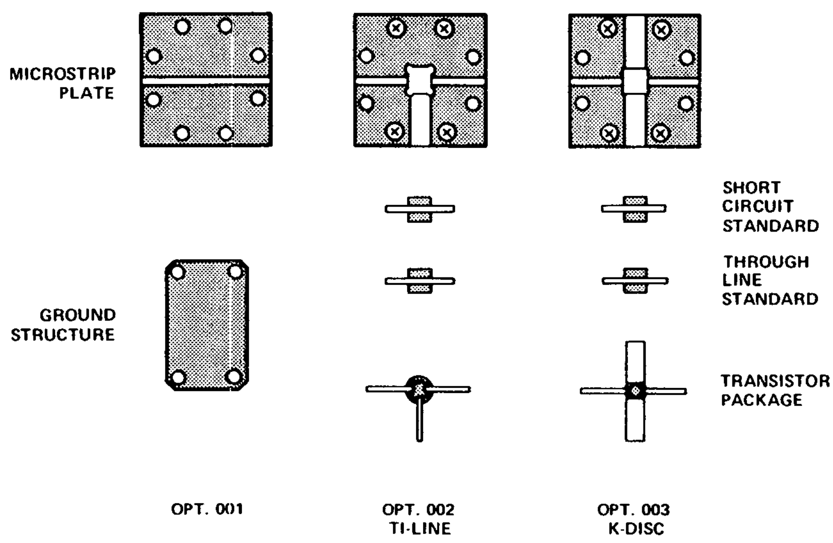


Figure 8. The Internal Structure of the 11608A

CALIBRATION UNITS

As explained in Application Note 117-1, the 8410A Network Analyzer measures the amplitude ratio and phase difference between the test and reference channels. It is, therefore, necessary to calibrate the measurement system prior to inserting the device, to establish a known ratio and phase difference. This is best achieved by inserting a calibration unit with a known amplitude and phase response into the test fixture and adjusting the operating controls until the display indicates the correct values.

Two calibration units are supplied with each 11608A Test Fixture with Option 002 or 003 (Figure 8). The Short Circuit calibration unit provides a package with the input and output leads shorted to ground at the point of entry to the case. The forward and reverse reflection coefficients (S_{11} and S_{22}) will, therefore, be $1.0\angle 180°$ with the point of entry to the case defined as the reference plane.

The Through Line calibration unit is a section of 50 ohm microstrip of known length, which may be used to simulate a transmission coefficient of $1.0\angle 0.0°$.

No calibration units are supplied with the 11608A Option 001 since the package style is not defined. A short circuit and through line must be constructed. (See page 5-3.)

CHAPTER III
APPLYING BIAS TO THE TRANSISTOR

BIAS FEED VIA THE 8746B

Bias may be applied to the transistor under test via the appropriate input connections on the 36-pin connector at the rear of the 8746B. Figure 9 shows the six pins required for bias supply.

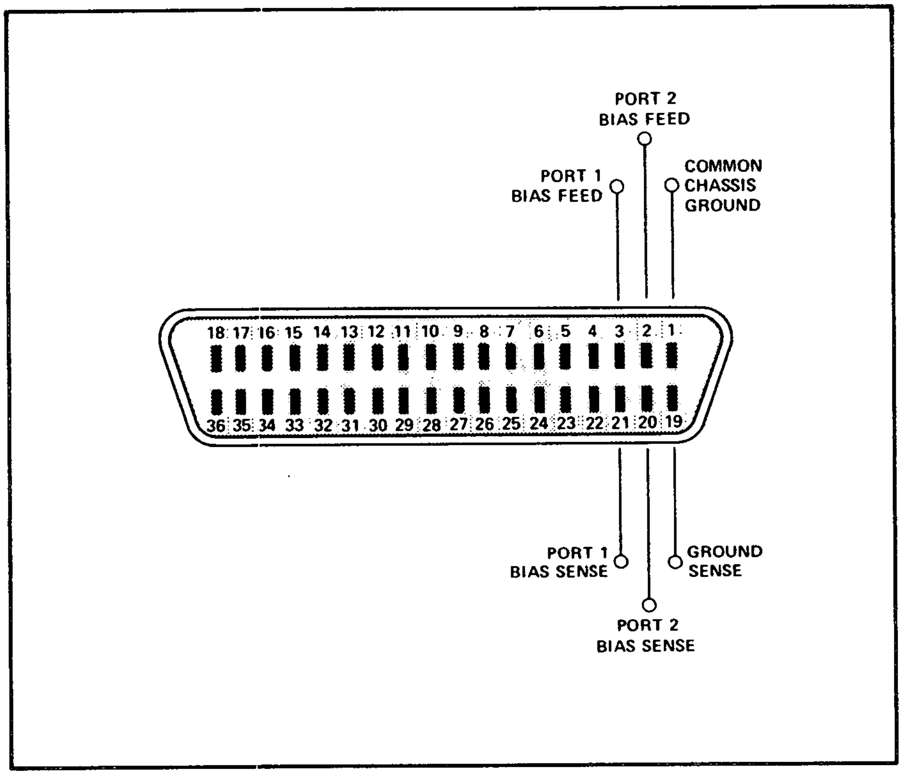


Figure 9. Bias Connections to the 8746B Rear Panel Connector

PIN 1 — Common chassis ground

PIN 2 — Port 2 bias feed. Connects to center conductor or Port 2.

PIN 3 — Port 1 bias feed. Connects to center conductor of Port 1.

PIN 19 — Ground sense. Terminal for sensing ground potential.

PIN 20 — Port 2 bias sense. Terminal for sensing Port 2 bias voltage at the port connector, for feedback control of a constant voltage supply.

PIN 21 — Port 1 bias sense. As for pin 20.

USE OF SENSE TERMINALS

The stability, output impedance, output voltage and other parameters of a power supply, are normally specified with respect to the supply output terminals. However, when measured at the end of leads connecting the supply to a device, these parameters are different due to the losses and the subsequent loading effect of the leads. To overcome this problem, many power supplies have provision for external feedback or sensing leads, which allow direct control of the output voltage at the point of connection to the device.

Pin numbers 19, 20, 21 on the 8746B rear panel connector provide connection points for sensing leads when these are required.

When using normal power supplies and bias conditions, these terminals may be ignored or may be used in parallel with the corresponding bias feed terminal to double the current capability (0.5A maximum to 1.0A maximum).

USING DUAL POWER SUPPLIES

A convenient method of supplying bias to the transistor is to use two independent power supplies, with voltage and current monitoring. A resistor may be used to limit the emitter current to a safe value.

The circuit connections for such a dual supply system are given in the following procedures.

USING THE 8717A TRANSISTOR BIAS SUPPLY

The 8717A Power Supply has been designed specifically for biasing transistors. It provides easy switching between different operating modes and lead configurations and allows monitoring of the voltage or current at any junction. A cable is supplied to mate directly with the rear panel connector on the 8746B. No other connections are necessary.

The 8717A contains two independent supplies. One operates in a constant voltage mode to supply a preset operating voltage. The second operates as a constant current source, with a feedback circuit to maintain a constant emitter current, even if the DC load conditions change from device to device.

CONFIGURATION OF BIAS SUPPLIES

The following procedures will allow the correct bias conditions to be set for any type of device using either dual power supplies or the 8717A Transistor Bias Supply.

1. Determine the type of device — Bipolar or FET.

2. Determine the polarity — PNP or NPN for Bipolar transistors P-CHANNEL or N-CHANNEL for FET's.

3. Determine the lead configuration. Common base, common emitter or common collector for bipolar transistors. Common gate, common source or common drain for FET's.

4. Turn to Figure 11 for common emitter or common source.
Turn to Figure 12 for common base or common gate.
Turn to Figure 13 for common collector or common drain.

5. Set the 8717A slide switches as shown or wire the appropriate power supply connections as shown. The resistor provides overload protection.

6. If using the 8717A, set the voltage and current monitoring controls and emitter (source) overload limit to suit the bias to be supplied. Turn voltage and current adjustment controls to zero (fully counterclockwise) (see Figure 10).

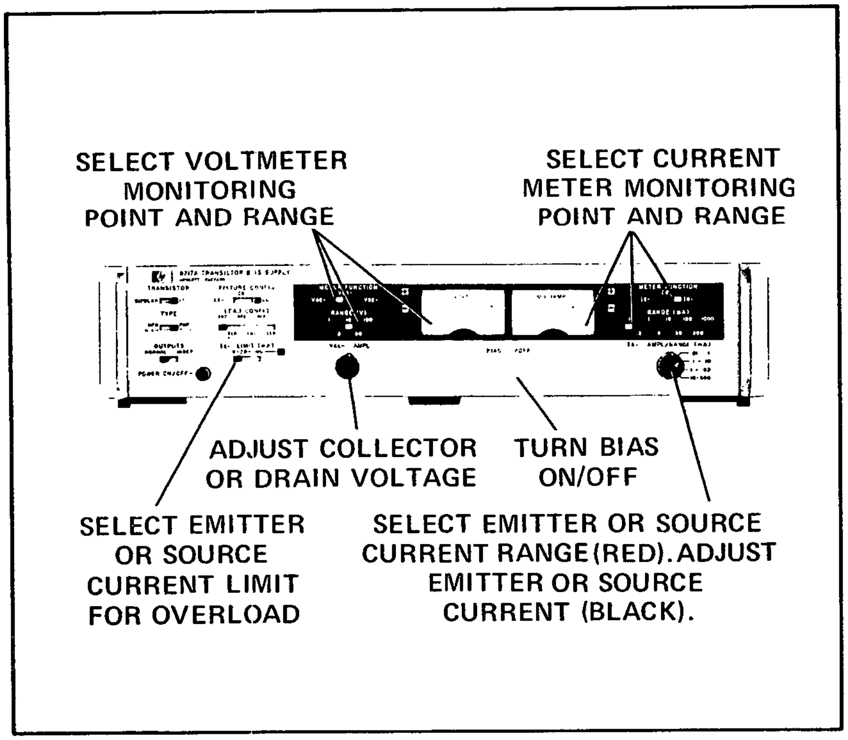


Figure 10. Operating Controls of the 8717A Power Supply

7. If using separate supplies, select voltage and/or current ranges and turn adjustment controls to zero.
8. Turn on bias supplies.
9. Insert the device.
10. Increase first voltage and then current to required levels.
11. After measurement has been made, turn the current and then the voltage control to zero *before removing the device.*

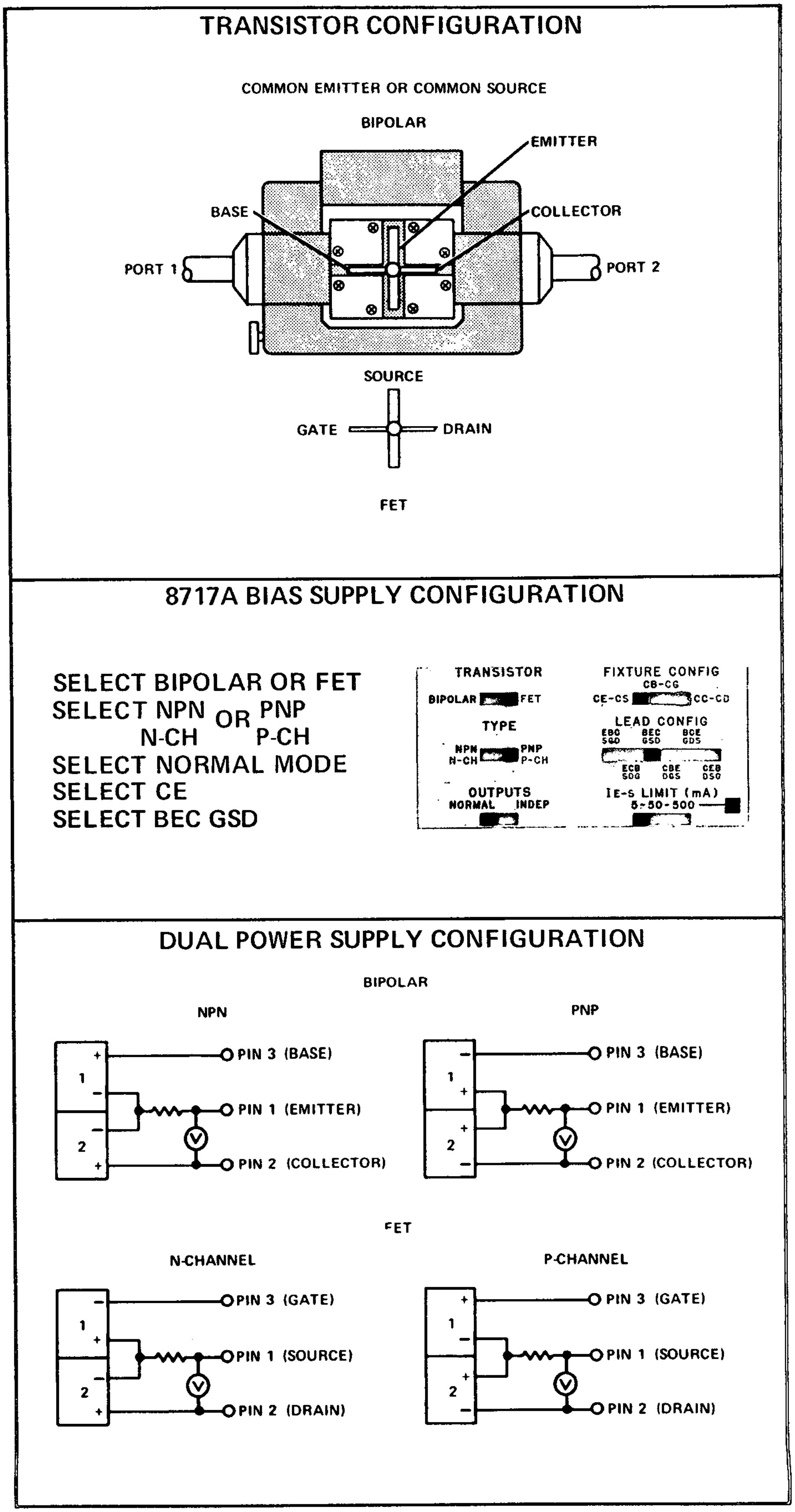
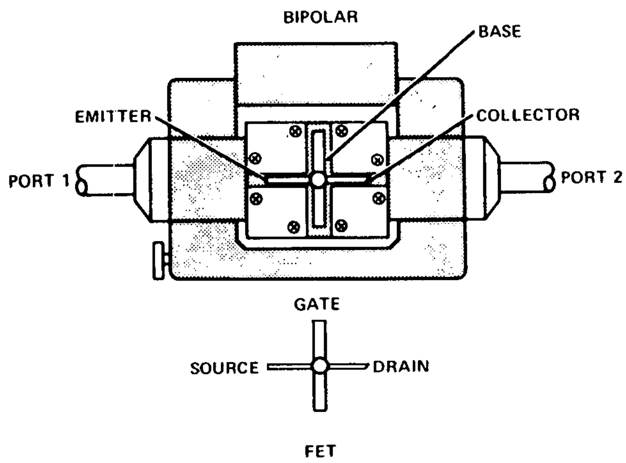


Figure 11. Bias Supply Configuration for Common Emitter

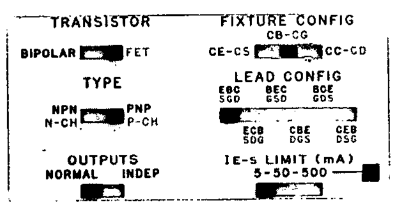
TRANSISTOR CONFIGURATION

COMMON BASE OR COMMON GATE



8717A BIAS SUPPLY CONFIGURATION

SELECT BIPOLAR OR FET
SELECT NPN OR PNP
N-CH OR P-CH
SELECT NORMAL MODE
SELECT CB
SELECT EBC/SGD



DUAL POWER SUPPLY CONFIGURATION

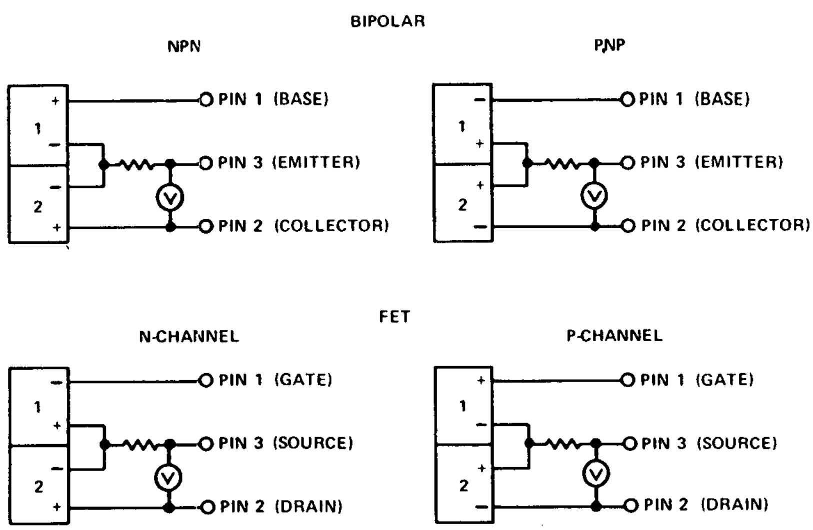


Figure 12. Bias Supply Configuration for Common Base

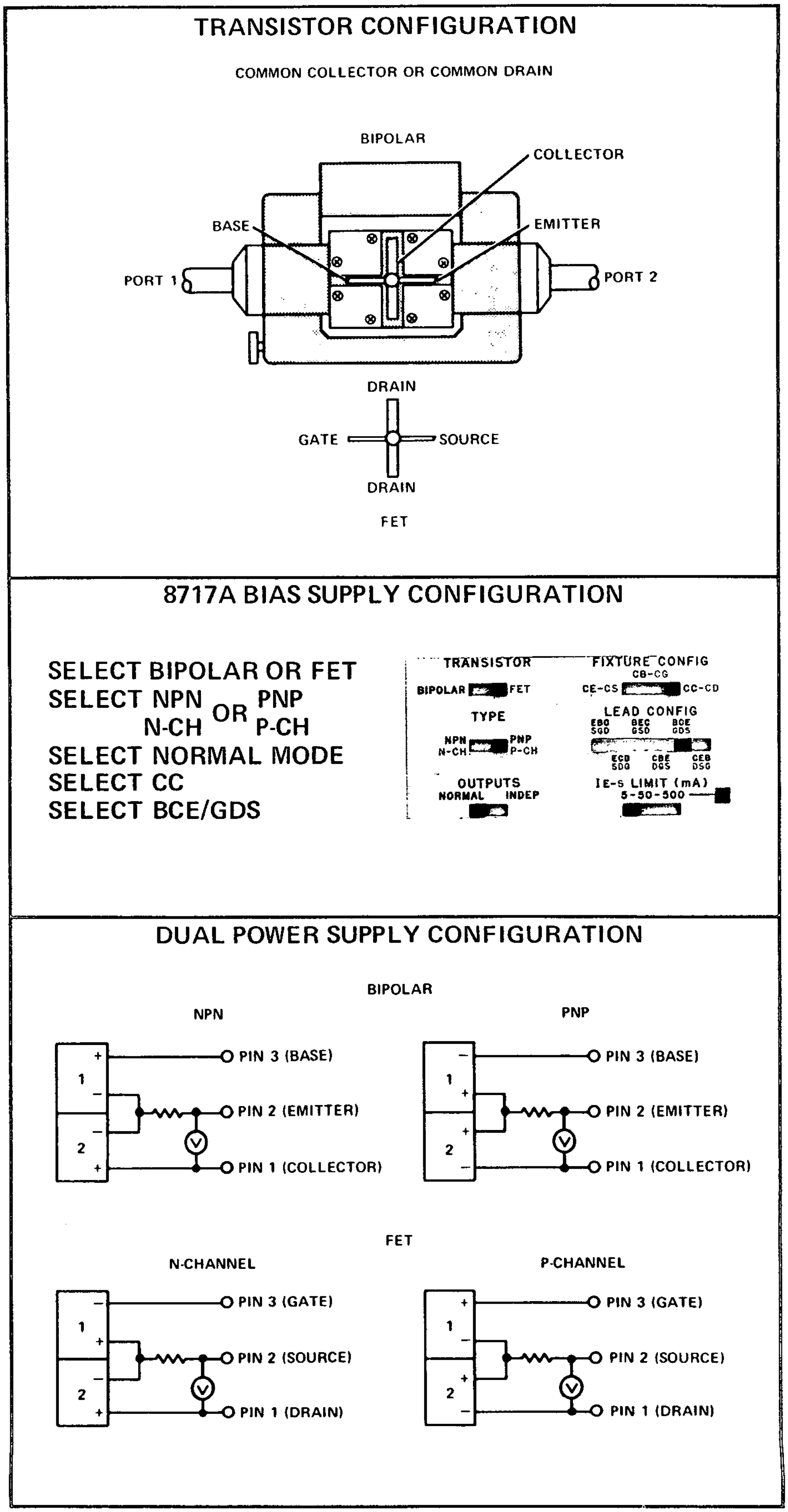


Figure 13. Bias Supply Configuration for Common Collector

CHAPTER IV
MEASURING TRANSISTOR PARAMETERS

This section describes the operating procedures which will provide optimum measurement of stripline transistors.

The measurement system should be assembled and connected as shown in Figure 14, with the required display unit plugged into the Network Analyzer mainframe.

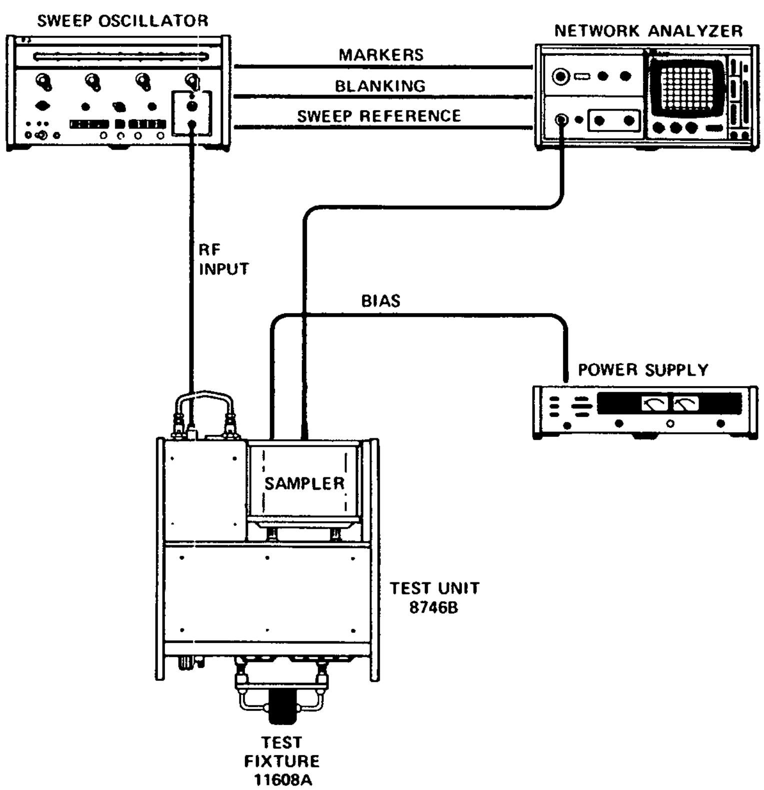


Figure 14. System Interconnection Diagram

Reference should be made to the appropriate operating and service manual supplied with each instrument, for detailed instructions on the operation of individual controls. If remote control of the 8746B is to be employed, or if bias is required, the correct interconnections must be made to the rear panel 36-way connector on the 8746B Test Unit.

If possible, allow approximately 20 minutes for all instruments to warm up before calibrating, so that operating conditions can stabilize.

SETUP PROCEDURES

1. **SWEEPER CONTROLS**

   a. Set the sweep range for an octave band within the frequency range.

   b. Set the SWEEP TIME to approximately 0.05 sec.

   c. Set the SWEEP SELECTOR switch to MANUAL.

2. **NETWORK ANALYZER CONTROLS**

   a. Set the FREQUENCY RANGE switch to cover the same frequency range as above.

   b. Set the TEST CHANNEL GAIN control to show 21 dB.

   c. Set the SWEEP STABILITY control to CW.

   d. Increase the RF power until the REF CHANNEL LEVEL indicator is showing a reading at the high end of the "OPERATE" region. This ensures enough power in the reference channel for phase locking.

   e. Rotate the MANUAL SWEEP control over the frequency range selected and observe the REF CHANNEL LEVEL indicator. If the needle moves into the right-hand black portion of the scale, reduce the RF power level to keep it within the operate region. The relationship between the Reference Channel Level and the power incident on the device is explained on page 4-3.

3. **TEST UNIT CONTROLS**

   When the 8746B is turned on, the S_{22} mode is automatically selected and the attenuator set to 70 dB. (The same conditions are set should power failure occur during a measurement.)

   Select 0 dB attenuation.

4. **DISPLAY UNIT CONTROLS**

   a. Set the SWEEP SELECTOR control of the 8690B or 8620A to automatic sweep.

   b. For the Phase-Magnitude Display (8412A) set the DISPLAY MODE to amplitude.

   c. For the Phase-Gain Indicator (8413A) use an external oscilloscope to display the magnitude of the test signal.

   d. For the Polar Display (8414A), if a dot appears on the screen, extend the REFERENCE PLANE EXTENSION control on the Test Unit (8746B) until the dot extends to a semicircular trace. If no dot or line trace appears, decrease the test channel gain.

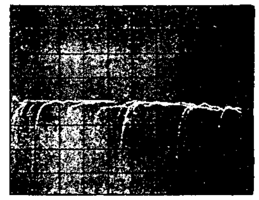
5. **PHASE LOCK SETTING**

   a. Adjust the red SWEEP STABILITY control on the 8410A, until the display trace is a solid line over the entire sweep. This indicates that phase-lock has been achieved over the entire frequency range.

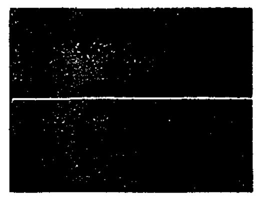
   b. In some cases, better phase-lock may be achieved by setting the FREQUENCY RANGE switch on the 8410A one or two notches on either side of the exact range.

   c. Should any difficulty be encountered in setting for correct phase-lock operation, ensure that the SWEEP REFERENCE connection is made between the sweeper and network analyzer and reduce the sweep speed.

HP 8412A INCORRECT PHASE LOCK



HP 8412A CORRECT PHASE LOCK



SETTING INCIDENT RF POWER LEVEL

When measuring active devices, such as stripline transistors, it is important to establish the power incident on the device to ensure that the device operates in the linear region.

As explained on page 1-4, the standard 8746B Test Unit is optimized for small signal S-parameter measurements and the power level at the output port is approximately -6 dBm when the REFERENCE CHANNEL LEVEL indicator on the 8410A is set to the top end of the operate region and the 8746B attenuator is set to zero. When the indicator shows mid-scale, the corresponding power level is -20 dBm, approximately.

For a more accurate determination of incident power levels, an RF Power Meter such as HP Model 432A with Model 478A Thermistor Mount, should be connected to the output port (APC-7 to N-Type adapter will be required) and the power level measured. The sweeper power level control may be used as a vernier, to adjust to a convenient reference value. The 0 to 70 dB attenuator in the 8746B test unit allows the incident power to be decreased while maintaining the reference channel power for good phase-lock operation.

SYSTEM CALIBRATION

When the basic operating conditions have been set and the required power level determined, the system can be calibrated.

1. **CALIBRATION FOR S_{11} AND S_{22} MEASUREMENTS.**

   It is necessary to establish the phase reference plane and a known amplitude level. These conditions can be achieved by using a short-circuit calibration unit in place of the device, to give a reflection coefficient of $1.0\angle 180°$.

   a. Ensure that the bias supplies are turned off.

b. Insert the SHORT CIRCUIT calibration unit into the 11608A Test Fixture, ensuring that the leads seat correctly onto the input and output connections.

c. Close the lid of the Test Fixture until the spring catch engages.

d. Select S_{11}.

Using the 8413A Display Unit

a. If the 8413A Phase-Gain indicator is being used in the swept mode, decrease the sweep speed to 1.0 second and depress the 30 dB amplitude sensitivity button.

b. Adjust the TEST CHANNEL GAIN control on the 8410A to bring the reading to the center zero line.

c. Increase the sensitivity by selecting the 3 dB amplitude position and repeat step b.

d. Use the AMPLITUDE VERNIER control on the 8410A Network Analyzer, to bring the reading to exactly zero.

e. Adjust the PHASE OFFSET control on the 8413A to a reading of ±180°.

f. Depress the 180° phase angle sensitivity button.

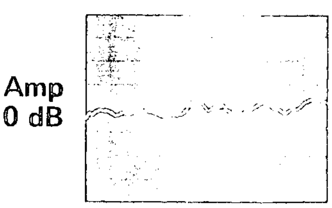
g. Adjust the REFERENCE PLANE on the 8746B to bring the oscillation of the needle to a minimum.

h. Depress the 6° phase angle sensitivity and again adjust the REFERENCE PLANE for minimum oscillation of the needle.

i. Adjust the PHASE VERNIER to center the oscillation about the zero mark. For large sweep widths, the oscillation of the needle will not reduce to zero due to residual tracking errors within the system. For maximum accuracy at CW frequencies, the calibration procedure should be repeated for each frequency of interest. The sweep speed may now be returned to the 0.01 second position and an oscilloscope attached to the calibrated amplitude and phase outputs.

More details on the use of the 8413A will be found in AN 117-1.

AMPLITUDE = 0 dB



Using the 8412A Display

a. Set the mode switch to AMPL and the amplitude sensitivity to 10 dB/div.

b. Adjust the TEST CHANNEL GAIN on the 8410A to bring the horizontal line to the center of the graticule.

c. Increase the sensitivity to 1.0 dB/div and adjust the AMPLITUDE VERNIER to bring the line exactly to the graticule center.

d. Select the PHASE mode with a phase sensitivity of 90°/div.

e. Select a phase offset of ±180°.

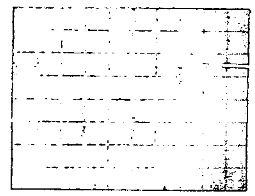
f. Adjust the REFERENCE PLANE EXTENSION on the 8746B to bring the sweep display to a horizontal line.

g. Increase the phase sensitivity to 1.0°/div and adjust the PHASE VERNIER to bring the sweep to the center graticule line.

h. Repeat steps f and g if necessary. For large sweep widths, the display will not be a perfect horizontal line due to the residual tracking errors within the system.

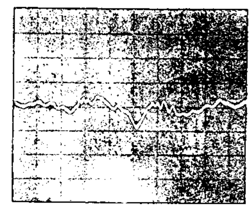
FLAT HORIZONTAL LINE

Phase 0°



180° PHASE SHIFT

Phase 180°



Using the 8414A Display

a. Depress the BEAM CENTER button and adjust the spot to the center of the display using the vertical and horizontal shift controls.

b. Adjust the REFERENCE PLANE EXTENSION on the 8746B to collapse the line trace to a dot or small cluster.

c. Adjust the PHASE VERNIER to move the dot to the 180° radial axis.

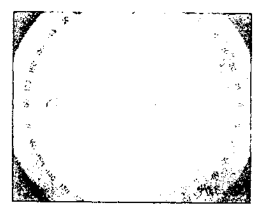
d. Adjust the AMPLITUDE VERNIER AND TEST CHANNEL GAIN on the 8410A, to move the dot to the outer circle.

The system is now calibrated to a reflection coefficient of 1.0∠180° and the REFERENCE PLANE ZERO may be set to 0.00. After calibrating for S_{11}, select S_{22} and observe that the calibration is still approximately valid. The directional couplers used in the 8746B have been designed to give minimum tracking error and the incident and reflected path lengths for S_{11} and S_{22} have been equalized to within 1 mm. This means that it will not usually be necessary to calibrate independently for S_{11} and S_{22}, except for the most precise measurements.

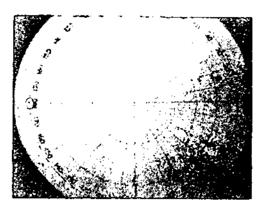
Should precise calibration for S_{22} be required, select S_{22} and repeat the above procedures.

SMALLEST CLUSTER

DOT POSITIONING ON 180° LINE



ρ = 1.0 180°



2. CALIBRATION FOR S_{12} AND S_{21}

To calibrate the system for the transmission parameters S_{12} and S_{21}, the THROUGH LINE calibration unit is used. This has an assumed response of 0 dB loss and a known electrical length (specified with the unit) which is sufficient to define the phase reference point.

a. Ensure that all bias supplies are turned off.

b. Select S_{21}.

c. Insert the THROUGH LINE calibration unit into the 11608A Fixture ensuring that the leads seat correctly onto the input and output connections.

d. Close the lid until the spring catch engages.

Using the 8413A Phase-Gain Indicator

Follow the procedure given above for S_{11}, except that in step e set the PHASE OFFSET CONTROL to 0° not 180°.

Using the 8412A Phase Magnitude Display

Follow the procedure given above for S_{11} except that in step e the phase offset should be 0° not 180°.

Using the 8414A Polar Display ,

Follow the procedure given above for S_{11} except that in step c adjust the PHASE VERNIER to move the dot to the 0° radial axis, not the 180° radial axis.

The system will now be calibrated for transmission measurements, except that the electrical length of the through line has been compensated by adjusting for a 0° phase response. To remove this offset and re-establish the reference planes at the input and output planes of the device, hold the REFERENCE PLANE EXTENSION control firmly to prevent rotation. Adjust the ZERO control until a reading is shown equal to half the electrical length specified for the through line calibration unit. When this has been set, release the reference plane extension control and rotate it until the reading is again 00.0. The reference planes are now set correctly.

Following calibration for S_{21}, select the S_{12} mode and observe that the calibration remains approximately valid. This means that it will not usually be necessary to recalibrate for S_{12} separately, except for the most precise measurements.

If the SHORT CIRCUIT calibration unit is now replaced and S_{11} or S_{22} selected, it will be found that these parameters are also calibrated approximately. This shows that the internal path lengths are accurately compensated and means that a single calibration with the THROUGH LINE or the SHORT CIRCUIT will be sufficient for the measurement of all four S-parameters with nominal accuracy.

As the frequency of operation is increased, the observable differences will increase, since the phase offset introduced by slightly unequal path lengths becomes larger.

DEVICE MEASUREMENTS

Once the system has been calibrated, devices may be characterized by the following procedure:

1. Setup the correct bias supply configuration as described in Chapter III.
2. Turn on bias supplies but ensure that the output voltage controls are set to zero.
3. Insert the device ensuring that all leads seat correctly and close the lid of the 11608A Fixture until the spring catch engages.
4. Increase the collector/emitter voltage to the required level.
5. Increase the base/emitter voltage to give the required operating current.
6. Select the desired parameter and the frequency limits and observe the display.
7. BEFORE UNLATCHING THE LID OF THE 11608A FIXTURE, decrease first the base/emitter voltage, then the collector/emitter voltage to zero.

Great care should be taken when setting the bias levels to ensure that excess voltage, switching transients, or loose connections do not cause burn-out of sensitive devices.

INTERPRETING THE DISPLAY

8413A Phase-Gain Indicator

When measuring S_{11} or S_{22}, the 8413A indicates the return loss in dB or the phase change occurring on reflection.

When measuring S_{12} or S_{21}, the 8413A indicates the gain or loss of the device in dB or the phase change across the device. This display is most useful for fixed frequency measurements, but a swept display is possible by using an external oscilloscope.

8412A Phase-Amplitude Display

A superior swept frequency display of return loss and phase for S_{11} and S_{22} or gain/loss and phase for S_{12} and S_{21}, is provided by the 8412A display unit. The center horizontal graticule line represents 0 dB loss or zero degree phase angle and scale expansion is possible to a maximum of 0.25 dB/cm or 1.0°/cm.

8414A Polar Display

The 8414A provides a polar display of reflection coefficient (S_{11}, S_{22}) or transmission coefficient (S_{12}, S_{21}) as a radial distance from the display center. Five concentric graticule rings provide calibration marks of 0.2/division. Phase angle is displayed as rotation about the center with a radial line marking each ten degrees. A single dot may, therefore, represent both the magnitude and phase response of the device and the locus of the point shows the variation in both parameters as a function of frequency.

A transparent plastic overlay is provided, which converts the linear radial display to dB return loss. A further set of overlays provide an impedance calibration normalized to 50 ohms, in the form of a Smith Chart with a full scale reflection coefficient of 3.16, 1.0 or 0.2. These overlays correspond to TEST CHANNEL GAIN offsets on the 8410A of -10 dB, 0 dB and 14 dB. For example, when the system is calibrated using the short circuit, the display is set to a reading of $1.0\angle 180^\circ$ with a Test Channel Gain setting of, say, 21 dB. If the test channel gain is increased by 14 dB to 35 dB, the outer circle of the display becomes 0.2 reflection coefficient, and the appropriate overlay provides the corresponding section of a Smith Chart.

CHAPTER V
DESIGNING A TEST FIXTURE USING THE 11608A OPTION 001

BASIC REQUIREMENTS

The 11608A Option 001 Test Fixture is supplied with the basic internal structure left blank. Figure 15 shows the individual components which make up the complete fixture.

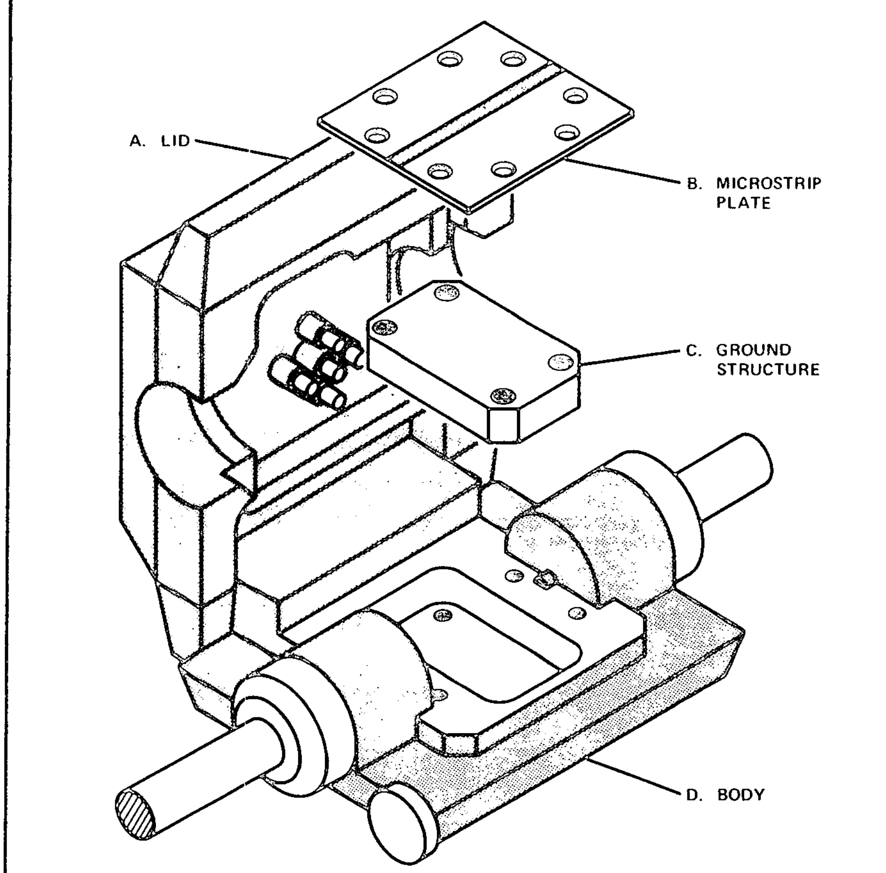


Figure 15. An Exploded View of the 11608A Test Fixture with Option 001

There are two ways in which the components may be modified.

1. Machine the 50 ohm Microstrip and ground structure to suit the device.

2. Replace the 50 ohm Microstrip with another section. This method will be necessary when a different thickness or a different type of dielectric material is required.

The standard 50 ohm Microstrip plate (B) is made from 0.0310 ±0.0005 inch thick Z-tron "H"* dielectric material which is a modified PPO** (polyphenylene oxide) with a dielectric constant of 2.72 ±0.02. This material may be machined using standard high speed drills and cutting tools. Two such plates are supplied.

The bonded stripline is 0.080 inch wide tapering to 0.076 inch in the center. The taper is designed to compensate for the added shunt capacitance of the clamp on the lid of the fixture. A copper ground plane is bonded to the reverse side and both surfaces are gold flashed.

The ground structure (C) is 0.234 inch thick brass with a gold flash plating. This thickness allows the final machined ground plate to have a top surface flush with the top of the microstrip board should the device require it. This means that the maximum depth clearance available is 0.20 inch unless the base of the fixture itself is machined.

The space available in the horizontal plane is a one-inch square which must accommodate both the body and the leads of any device.

Provided the above size limitations are observed, there should be no restriction on the type of device which may be measured.

Complete microstrip assemblies may be tested or individual device chips mounted on stripline board and the complete assembly tested.

The device does not have to be active. The high frequency performance of stripline capacitors and resistors may be determined by providing the appropriate mounting.

MAINTAINING THE ELECTRICAL ENVIRONMENT

To maintain the 50 ohm characteristic of the transmission line, the leads of any device must be narrower than the microstrip conductor (0.080 inch). If leads are wider than this, a new microstrip board must be made with a wider line. However, the wider geometry will degrade performance above 6 GHz.

A good ground contact is essential for accurate characterization of the device. When the effect of device leads is not to be included in the measurement, the ground contact should be made as near as possible to the device to avoid lead inductance. If it is desired to duplicate an actual operating circuit condition, the ground structure should duplicate the actual circuit as closely as possible.

The lid of the fixture holds five silicon rubber pads, four to clamp the device leads and a central one to clamp the body. If the body of the device is too thick or too fragile, the center pad may be removed.

The clamping structure provides some shunt capacitance to the microstrip and this should be compensated by tapering the line.

*Trademark of the Polymer Corporation
**Trademark of the General Electric Company

TUNING OF COMPLETE FIXTURE

As the frequency of operation increases, the residual losses and the effect of small perturbations increases also.

Above 4 GHz, it will be more difficult to manufacture the fixture to compensate for all perturbations. To allow for adjustment of the final structure, two tuning screws are provided, one at each end of the microstrip line, to give a variable shunt capacitance at the input and output. By measuring the "through" line and observing the Network Analyzer display, the screws may be adjusted for minimum residual response.

At the top of the frequency range (6 GHz to 12.4 GHz) the residual loss of the through line rises (approximately 0.75 dB) and adjustment of the tuning screws becomes more difficult. The best way of adjusting the fixture is to use a TDR (Time Domain Reflectometer) such as the HP 1815 System, which shows the response of the individual junctions within the fixture and allows the effect of tuning adjustments to be closely observed up to 12.4 GHz. Figure 16 shows typical TDR responses for the 11608A fixture with the through line calibration unit in place.

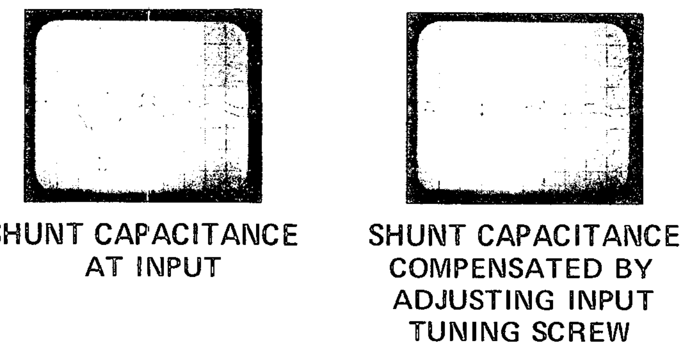


Figure 16. Typical TDR Responses

CALIBRATION UNITS

When the fixture has been machined to accept the particular device, suitable calibration units must be made.

Figure 17 shows the construction of typical short circuit and through line section.

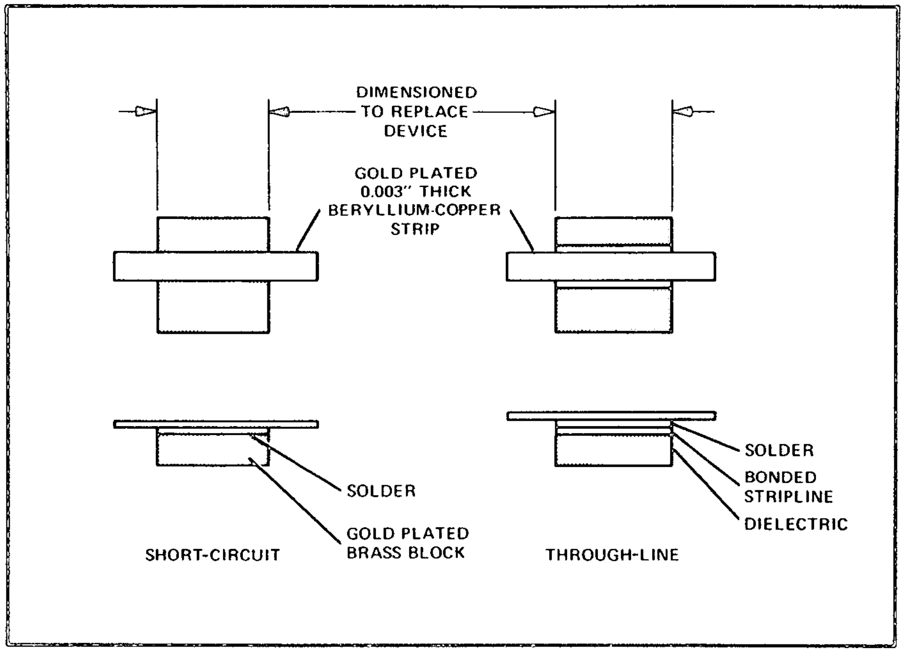


Figure 17. Typical Short Circuit and Through Line Calibration Units

CHAPTER VI
USING THE 8746B TEST UNIT WITHOUT THE 11608A FIXTURE

Although the 8746B Test Unit and 11608A Transistor Fixture were designed to give optimum performance when used together, the 8746B may be used as an independent test unit for the measurement of passive components or complete assemblies.

Used in this way, it has the advantage of a broader frequency range than the 8745A or 8743A Test Units. However, the 8743A has a higher directivity above 4 GHz (30 dB against 26 dB for the 8746B) and this unit should be used for optimum performance.

PATH LENGTH COMPENSATION

As was seen during the description of the calibration routine for transistor measurements, (page 4-3) the internal electrical path lengths of the 8746B Test Unit are matched as closely as possible, to provide the same path length for each of the four S-parameters. In this way, only a small phase offset occurs when the parameters are switched and a single calibration is approximately valid for all parameters.

The 11608A Transistor Fixture is electrically symmetrical between Port 1 and Port 2 and, therefore, to maintain the convenience of direct parameter switching with a single calibration, the connections to any other device must also be symmetrical. Any increase in the *total* external path length from Port 1 to Port 2 may be compensated by adjusting the Reference Plane Extension or changing the External Reference Channel Link.

PHASE OFFSET AS A FUNCTION OF PATH LENGTH AND FREQUENCY

When considering the compensation of path lengths, it is important to know the accuracy of matching which must be achieved for a given phase offset at different frequencies.

For example, if during a calibration of the system a phase reference plane is defined using the short circuit standards, (for say S_{11}) Figure 18 shows the phase offset which will be caused by unequal lengths in the remaining parameter modes (S_{12}, S_{21}, S_{22}).

For reflection measurements, the path difference is twice the physical length difference since the extra length occurs in both the incident and reflected paths.

Figure 18 may be used to calculate how closely the path lengths from Port 1 or Port 2 to the device under test, must be matched, to achieve a given phase error when only one parameter is calibrated.

USING THE 8746B WITH A SYMMETRICAL EXTERNAL CIRCUIT

Once a tolerable phase offset has been determined, approximately matched lengths of cable may be used. The input VSWR and through

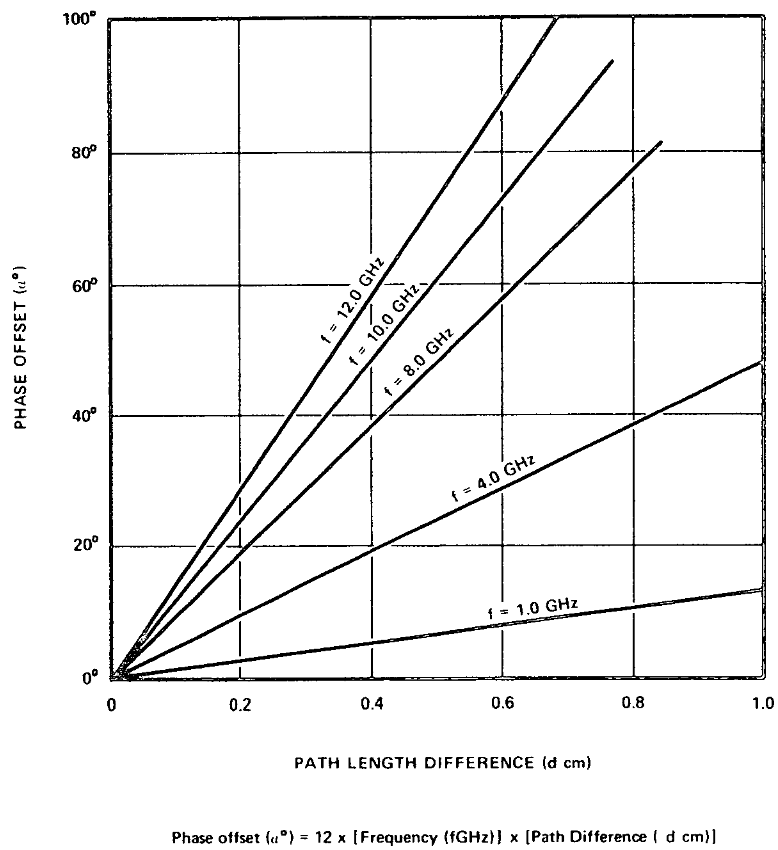


Figure 18. Linear Phase Offset as a Function of Path Length and Frequency

loss of the cables must be as low as possible otherwise the effective directivity of the test unit will be seriously reduced.

The best connections are made using semi-rigid coaxial cable.

Where more flexibility is required, two HP 11605A Flexible Arms may be used (as with the 8743A Test Unit) but the performance will be degraded by the residual VSWR of the 11605A (Figure 19).

USING A NON-SYMMETRICAL EXTERNAL CIRCUIT

Better performance may be achieved, particularly above 2 GHz by connecting the device directly to Port 1 and using a single 11605A Flexible Arm with a 10 dB pad to connect the output of the device to Port 2. This circuit arrangement is shown in Figure 20.

Using this technique destroys the symmetry of the external circuit so that separate calibrations and different Reference Channel Links are

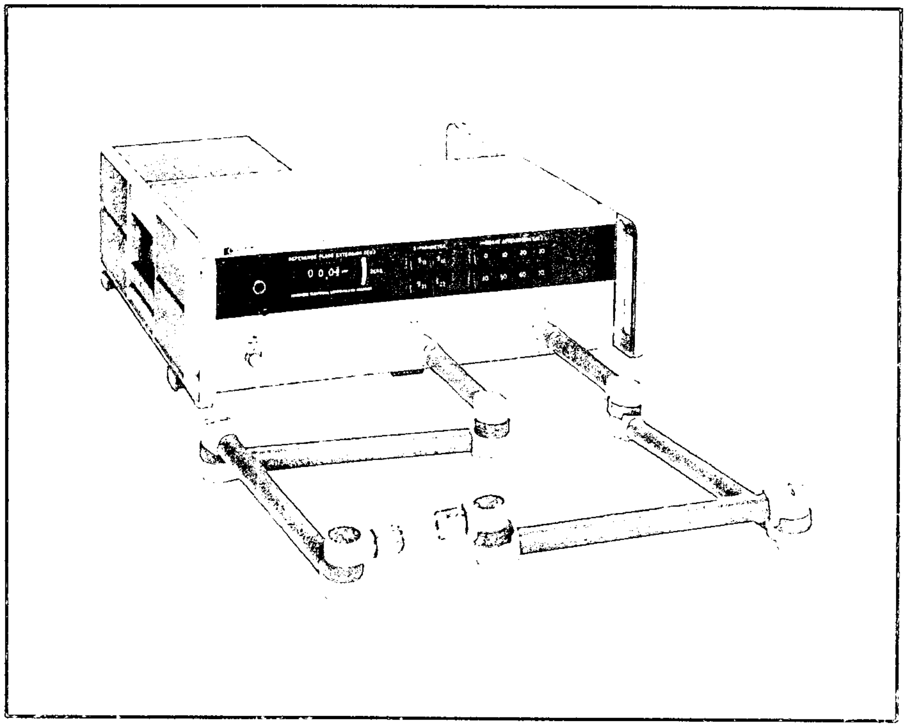


Figure 19. The 8746B Used with two 11605A Flexible Arms

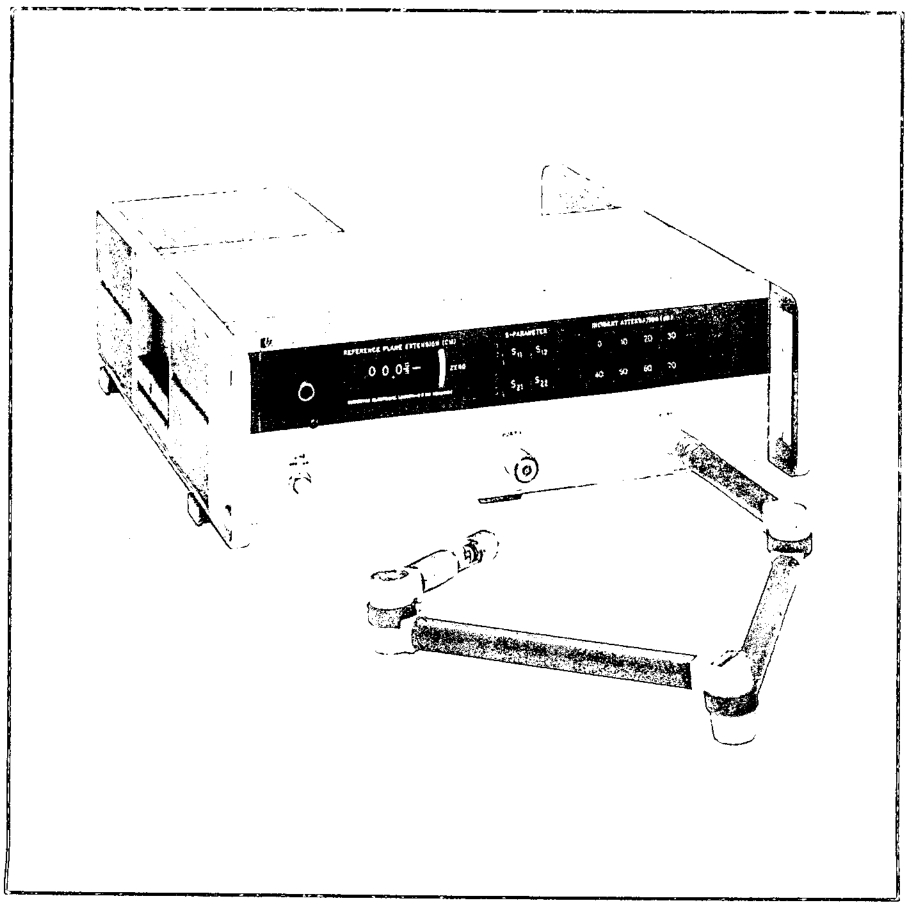


Figure 20. The 8746B Used with One 11605A Flexible Arm and One 8692B 10 dB Attenuator

required to measure the phase of S_{11} and S_{21} and the reverse parameters, S_{12} and S_{22}, are most easily measured by turning the device around.

Reference Channel Link, HP Part No. 08745-20064, will provide correct path length compensation for the calibration of S_{11}.

Reference Channel Link, HP Part No. 08746-20031, will provide correct compensation for S_{21} measurements when the 11605A Flexible Arm and an 8492B 10 dB pad are used as the return arm. The 10 dB pad reduces the effect of the input VSWR of the 11605A Arm.

The calibration technique when using this system is identical to that given in AN 117-1 for the 8743A Test Unit.

CHAPTER VII
STRIPLINE COMPONENT MEASUREMENTS WITH THE 8542A AUTOMATIC NETWORK ANALYZER

The 8542A Automatic Network Analyzer System combines the 8410A Network Analyzer with a small digital computer and multiband signal source to produce a completely integrated measurement system. Figure 21 shows a typical 8542A System.

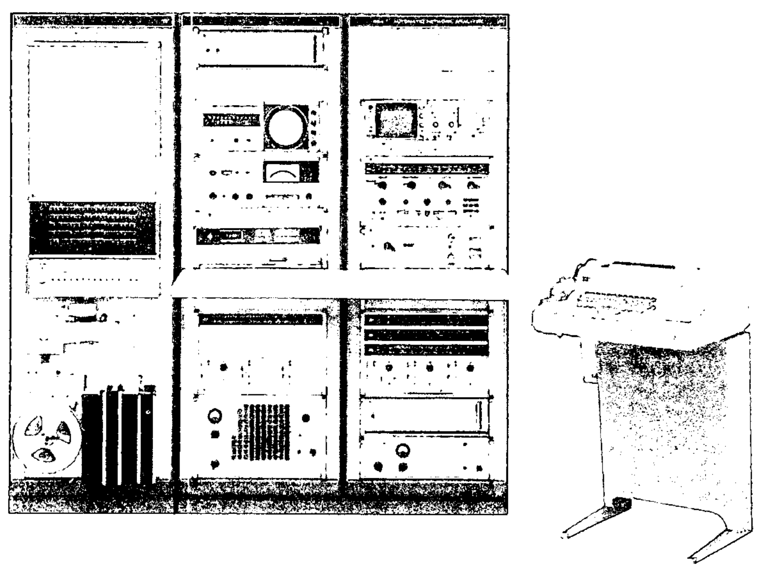


Figure 21. The 8542A Automatic Network Analyzer

The basic accuracy of the Network Analyzer is greatly enhanced by error correction techniques applied mathematically to the basic measured data. At the same time, all the necessary configuration and parameter switching is performed automatically, thus providing rapid, accurate measurements with little possibility of operator error.

The mathematical capability also allows the measured data to be converted to a more directly usable form and presented to the operator as printed data with the correct format and column headings, or in the form of a visual or printed graphical display, or as a punched paper tape.

The 8746B Test Unit and 11608A Test Fixture may form a part of an 8542A system thus providing the design engineer with highly accurate, broadband measurements of stripline components with on-line data reduction. The added benefit of a punched paper tape format provides for easy incorporation of the data into Computer Aided Design programs.

Engineers concerned with the production and incoming inspection of stripline components and assemblies have the capability for accurate, high-speed testing with minimal operator intervention and provision for limit detection and other decision making operations.

As an example of the flexibility of such a system, Figure 22 shows a typical printout following the measurement of a transistor. The basic S-parameters have been converted to gain and stability parameters which clearly indicate the performance of the transistor over a broad range of frequencies. Comparison of parameters such as these, for different devices, allows a quick selection of components for optimum multi-stage performance.

OPTION# 0
VCB= 15.00 VOLTS
IC= 15.00 MA

S -- MAGN AND ANGLES:

FREQ	11		21		12		22	
1000.0	.242	-166	3.367	76	.067	66	.623	-18
2000.0	.313	150	1.741	46	.117	61	.621	-29
3000.0	.386	127	1.225	23	.178	54	.597	-44
4000.0	.471	113	.951	4	.233	49	.603	-65
5000.0	.460	82	.818	-15	.308	28	.643	-96
6000.0	.468	67	.645	-29	.379	19	.749	-116

DESIGN PARAM.(IN DB IF APP.)

FREQ	H21	K	S21	GA(MAX)	G1	G2	GU(MAX)	U
1000.0	11.5	1.27	10.5	13.9	.3	2.1	12.9	.06
2000.0	5.2	1.27	4.8	8.6	.4	2.1	7.4	.07
3000.0	2.5	1.13	1.8	6.2	.7	1.9	4.4	.09
4000.0	.9	.95	-.4	*INF*	1.1	2.0	2.5	.13
5000.0	2.2	.78	-1.7	*INF*	1.0	2.3	1.6	.16
6000.0	2.2	.56	-3.8	*INF*	1.1	3.6	.8	.25

Figure 22. Typical Data Printout from the 8542A Automatic Network Analyzer

Further information on the 8542A Automatic Network Analyzer may be found in HP Journal, February 1970 and the 8542A Data Sheet. Both are available, on request, from your local HP sales office.

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AN 77-1 Transistor Parameter Measurements
AN 77-3 Complex Impedance Measurements
AN 92 Network Analysis at Microwave Frequencies
AN 95 S-Parameters . . . Circuit Analysis and Design
AN 117-1 Microwave Network Analyzer Applications

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