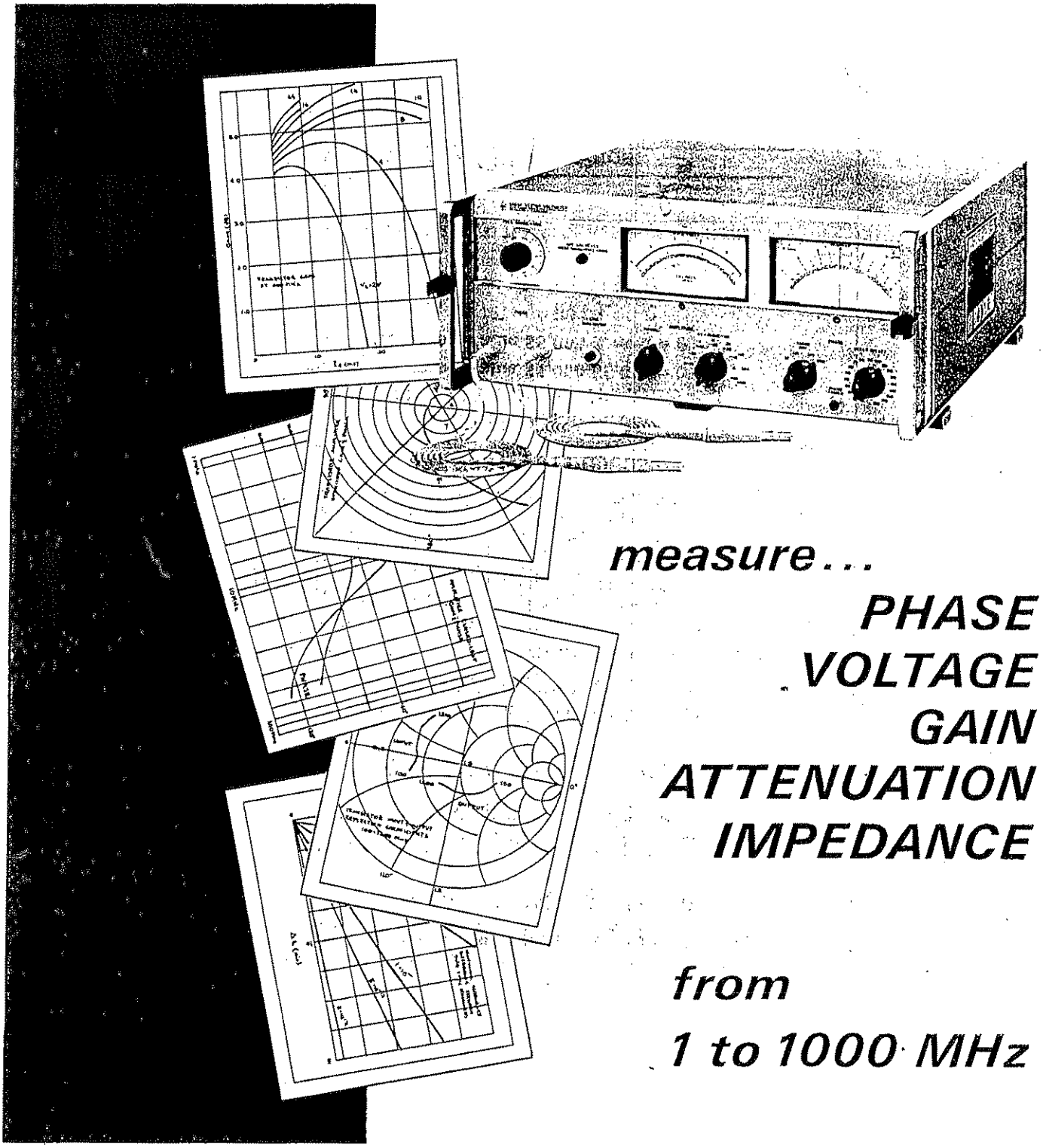
HEWLETT hp PACKARD

VECTOR VOLTMETER

model 8405A

ACCESSORY KIT 11570A

TECHNICAL DATA 1 JAN 7



measure...

PHASE
VOLTAGE
GAIN
ATTENUATION
IMPEDANCE

from
1 to 1000 MHz

For more information, call your local HP Sales Office or East (301) 948-6370 • Midwest (312) 255-9800 • South (404) 955-1500 • West (213) 877-1282. Or, write: Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304. In Europe, Post Office Box, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan, Yokogawa-Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151.

Frequency Range
from 1 to 1,000 MHz

Phasemeter
360° range with 0.1° resolution
± 180° offset in 10° steps

Dual Channel Millivoltmeter
100 μV full-scale sensitivity
>90-dB dynamic range

Simple Operation
automatic phase-locked tuning

Versatile Outputs
20 kHz replicas of RF inputs
voltmeter and phasemeter recorder outputs

USE TO MEASURE

- ► Amplifier gain and phase response
- ► Attenuation and phase characteristics of filters and other networks
- ► Cable characteristics
- ► Complex impedance, reflection coefficient, and SWR
- ► High-frequency transistor parameters
- ► Amplitude modulation percentage
- ► Small frequency differences
- ► Group delay

Magnitude and Phase

The Hewlett-Packard 8405A Vector Voltmeter provides the missing information in RF voltage measurements—**phase.** Since voltages are vector quantities described by both magnitude and phase, simple voltage measurements tell only half the story. Much circuit design is virtually impossible without phase information. Voltage and phase data define completely the network parameters needed to optimize any design. The 8405A allows you to measure, with one instrument, both voltage and phase over the wide frequency range of 1 to 1,000 MHz.

In addition to these valuable capabilities, the 8405A provides high accuracy and resolution, direct readout, and operating convenience. These features enable you to make RF voltage and phase measurements more easily than ever before. By making these measurements simple, the 8405A opens the door to new and more effective methods of component, network, and amplifier evaluation. The 8405A thus reduces costs by minimizing equipment requirements, saves time by simplifying measurements, and increases effectiveness by extending capability over a wide frequency range.

Meaningful 90 dB Dynamic Range

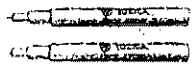
The 8405A is a two-channel, tuned volt/phasemeter with a 1-kHz bandwidth. It responds only to the fundamental frequency of the input signal, eliminating errors due to harmonics. It is as easy to operate as any untuned voltmeter and is well suited to fast production line testing. You simply rotate a front-panel switch to select any of the 21 overlapping octave ranges which include the input signal frequency, and the automatic phase-locked tuning does the rest. To eliminate guesswork, a front-panel light tells you when the voltmeter is properly tuned. The automatic tuning will follow slowly swept signals provided they remain within the selected octave range.

360° Phase Range, 0.1° Resolution

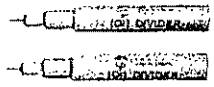
The phase difference between the two input channels is continuously displayed on a zero-center meter with end-scale ranges of ± 180°, ± 60°, ± 18°, and ± 6°. The ± 6° scale provides 0.1° resolution, and a meter offset selectable in precise 10° increments permits this resolution to be realized anywhere in the 360° range. A push-

ACCESSORIES

ACCESSORIES FURNISHED

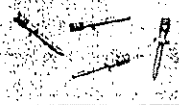


10216A Isolator (two furnished). Input impedance nominally 100 kΩ shunted by 5 pF. Used to eliminate errors due to effects of changing test point impedance.



11576A 10:1 Divider (two furnished). Input impedance nominally 1 MΩ shunted by 2 pF. Used to reduce voltage input 10 to 1. Also acts as isolator to eliminate errors due to effects of changing test point impedance.

10213-62102 Ground Clip (six furnished) for 11576A and 10216A.

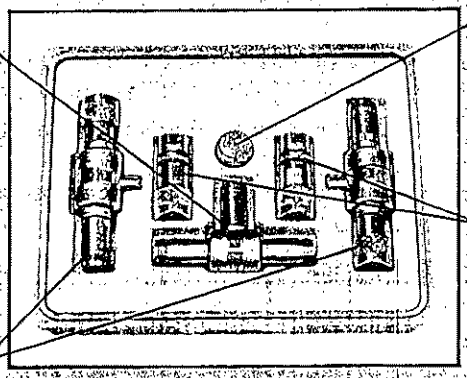


5020-0457 Probe Tip (six furnished).

10218A BNC Adapter (two furnished) converts probe tip to male BNC connector.

ACCESSORIES AVAILABLE

11549A Power Splitter, all connectors Type N female (UG-28A/U).



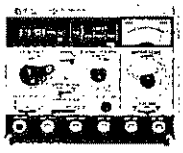
11512A Shorting Plug, Type N male.

908A Termination, for terminating 50Ω coaxial systems in their characteristic impedance.

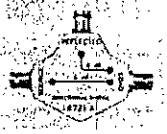
11536A 50Ω Tee, with Type N RF fittings, for monitoring signals in 50Ω transmission line without terminating the line.

11570A Accessory Kit. Essential for accurate measurements in 50Ω systems.

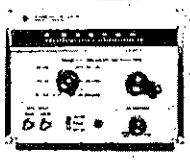
COMPLEMENTARY EQUIPMENT



8601A Generator/Sweeper. 1 to 110 MHz in one band. Greater than 2 volts into 50Ω. 0 to 130 dB attenuation.

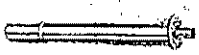


8721A Directional Bridge. 100 kHz to 100 MHz. This bridge has >40 dB directivity and <0.6 dB frequency response. Nominal coupling is 6 dB.



3200B 10 to 500 MHz Oscillator in 6 bands. Greater than 1 volt output into 50Ω. 0 to 120 dB attenuation.

8745A S-Parameter Test Set. Provides push-button convenience for measuring both reflection and transmission properties of networks. Has 36 dB directivity to 1 GHz. Additional accessories available include the 11600B/11602B Transistor Test Fixtures, the 11604A Flexible Arm, and the 11607A Small Signal Adapter.

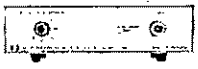


13515A Frequency Doubler extends 3200B to 1000 MHz. Approximately 0.5 volt output.

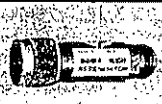
774D Dual Directional Coupler, 215 to 450 MHz. Also useful for complex impedance measurements below 215 MHz.

775D Dual Directional Coupler, 450 to 950 MHz.

778D Dual Directional Coupler, 100 to 2000 MHz, 36-dB directivity below 1000 MHz.



8502 Transmission/Reflection Test Set combines power splitter, 70 dB step attenuator and a high directivity (>40 dB) reflectometer bridge for 50 or 75Ω measurements from 1 MHz to 1 GHz.



8491A Coaxial Attenuators, 3-, 6-, 10-, and 20-dB. Use to isolate test from reference channel.

SPECIFICATIONS

INPUT CHARACTERISTICS

Instrument Type: Two-channel sampling RF millivoltmeter-phasemeter which measures voltage of two signals and simultaneously displays the phase angle between the two signals.

Frequency Range: 1 MHz to 1 GHz in 21 overlapping octave bands (lowest band covers two octaves).

Tuning: Automatic within each band. Automatic phase control (APC) circuit responds to the Channel A input signal. Search and lock time, approximately 10 milliseconds.

Voltage Range

Channel A:
1 to 10 MHz: 1.5 mV to 1 V rms.
10 to 500 MHz: 300 μV to 1 V rms.
500 to 1,000 MHz: 500 μV to 1 V rms.
Can be extended by a factor of 10 with 11576A 10:1 Divider.

Channel B: 100 μV to 1 V rms full scale (input to Channel A required); can be extended by a factor of 10 with 11576A 10:1 Divider.

Input Impedance (nominal): 0.1 megohm shunted by approximately 2.5 pF; 1 megohm shunted by approximately 2 pF when 11576A 10:1 Divider is used; 0.1 megohm shunted by approximately 5 pF when 10216A Isolator is used. AC-coupled.

Isolation Between Channels:
1 to 300 MHz: greater than 100 dB.
300 to 1,000 MHz: greater than 80 dB.

Maximum AC Input: 2 V peak.

Maximum DC Input: ± 50 V.

VOLTMETER CHARACTERISTICS

Meter Ranges: 100 μV to 1 V rms full scale in 10-dB steps. Meter indicates amplitude of the fundamental component of the input signal.

Voltage Accuracy: When accessories are used on one or both probes.

Accessory	Impedance		Frequency	Accuracy
HP 11536A 50Ω Feed-through Tee	50Ω		1-100 MHz	± 2% of full scale
	Freq.	SWR	100-300 MHz	± 6% of f.s.
	1-750 MHz 1-1000 MHz	< 1.15 < 1.20	300-1000 MHz	± 12% of f.s.*
HP 11576A 10:1 Divider	1 MΩ ∥ 2 pF equiv. to $\lvert Z\rvert = \frac{80}{f_{(MHz)}}$ kΩ from 5-100 MHz		1-100 MHz	± 6% of f.s.
HP 10216A Isolator	100 kΩ ∥ 5 pF equiv. to $\lvert Z\rvert = \frac{32}{f_{(MHz)}}$ kΩ from 15-200 MHz		1-200 MHz	± 6% of f.s.

* Above 300 mV and 800 MHz add ± 5%.

Voltage Ratio Accuracy: 0.2 dB.

Residual Noise: Less than 10 μV as indicated on the meter.

Bandwidth: 1 kHz.

GENERAL

20-kHz IF Output (each channel): Reconstructed signals, with 20-k fundamental components, having the same amplitude, wavefor and phase relationship as the input signals. Output impedance, 1,0 ohms in series with 2,000 pF; BNC female connectors.

Recorder Output:

Amplitude: 0 to + 1 V dc ± 6% open circuit, proportional to vo meter reading in volts. Output tracks voltage reading with ± 0.5% of full scale. Output impedance, 1,000 ohms; BN female connector.

Phase: 0 to ± 0.5 V dc ± 6%, proportional to phasemeter readin External load greater than 10,000 ohms affects recorder outp and meter reading less than 1%. Output tracks meter readir within ± 1.5% of end scale; BNC female connector.

RFI: Conducted and radiated leakage limits are below those specifie in MIL-I-6181D and MIL-I-16910C except for pulses emitted fro probes. Spectral intensity of these pulses is approximately 60 μV MHz; spectrum extends to approximately 2 GHz. Pulse rate varie from 1 to 2 MHz.

Power: 115 or 230 V ± 10%, 50 to 400 Hz, 35 watts.

Weight: Net, 30 lb (13,5 kg). Shipping, 35 lb (15,8 kg).

Dimensions: 18⅜ x 7 x 16¾ in. (467 x 177 x 425 mm).

Accessories Furnished: See page 6.

PHASEMETER CHARACTERISTICS

Phase Range: 360°, indicated on zero-center meter with end-scal ranges of ± 180, ± 60, ± 18, and ± 6°. Meter indicates phas difference between the fundamental components of the input signals

Resolution: 0.1° at any phase angle.

Meter Offset: ± 180° in 10° steps.

Phase Accuracy: At single frequency 1.5° (equal voltage at Channe A and B).

Phase accuracy vs. voltage.

Accessory	Frequency	Voltage Channel A or B	Phase Accuracy**
HP 11536A 50Ω Feed-through Tee	1-500 MHz	100 μV to 300 mV	± 3°
	500-1000 MHz	100 μV to 100 mV	± 3°
HP 11576A 10:1 Divider	1-100 MHz	1 mV to 3 V	± 4°
HP 10216A Isolator	1-200 MHz	100 μV to 300 mV	± 6°

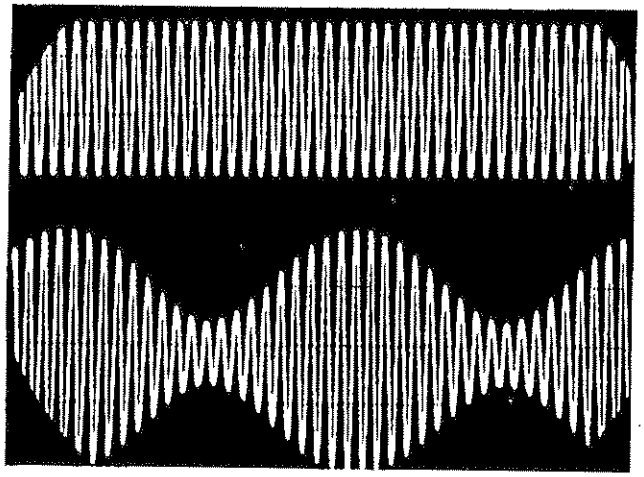
** To be added to single-frequency accuracy (± 1.5°) when the voltages at Channel A and B are not equal.

Phase Jitter vs. Channel B Input Level
Greater than 700 μV: Typically less than 0.1° p-p.
125 to 700 μV: Typically less than 0.5° p-p.
20 to 125 μV: Typically less than 2° p-p.

RF to AF converter

Because of the coherent sampling principle used in the 8405A, all RF frequencies are reconstructed at a low frequency of 20 kHz. This frequency can be observed on a low-frequency oscilloscope, wave analyzer, or spectrum analyzer. Modulation analysis can be performed since typical low-frequency modulation signals such as 400 Hz and 1,000 Hz are maintained on the IF output—as shown in the traces below.

Thus, an inexpensive oscilloscope can be used to read percentage AM on an RF carrier as high as 1 GHz, a wave analyzer can be used to analyze modulation sidebands for distortion, and an audio spectrum analyzer can serve to resolve and display narrow band modulation on an RF carrier. Since the 20-kHz output is constant and independent of the drift of the RF signal, displays are stable and jitter free.



Reconstructed signal at 20 kHz IF Output. Input signal: 125 MHz CW (upper trace); 125 MHz CW with 1,000 Hz, 60% AM (lower trace).

Other uses

Many additional applications are possible, including attenuation and filter resonance and response measurements. In such measurements, the wide dynamic range of the 8405A is extremely valuable. Frequency comparison is another application for which the 8405A is ideally suited. A few minutes of monitoring phase drift between two sources provides the same resolution as hours and days of direct frequency comparisons. Also, cable lengths can be measured and matched accurately through phase measurements. These and other applications are described briefly in the Hewlett-Packard Journal, Vol. 17, No. 9 (May, 1966).

Application Notes

Specific applications are covered in detail in an Application Note series. Application Note 77-1, Transistor Parameter Measurements, describes the measurement and use of "s" or scattering parameters to completely characterize a transistor. These parameters are easy to measure at frequencies up to 1 GHz with the 8405A, whereas h, y, and z parameters become difficult to work with above 100 MHz. Application Note 77-3, Measurement of Complex Impedance, 1-1,000 MHz, describes methods for the rapid determination of impedance in 50Ω systems using the 8405A and accessories. Application Note 77-4, Swept-Frequency Group Delay Measurements, describes a unique technique of making swept group delay measurements at frequencies through P band. Application Note 91, How Vector Measurements Expand Design Capabilities, describes several design applications using the 8405A. These Application Notes are available on request from any Hewlett-Packard Field Office.

Operation

The 8405A uses the sampling technique to convert the input signals to 20-kHz replicas having the same amplitude, waveform, and phase relationship as the input signals. These 20-kHz signals are then filtered so that only 20-kHz sinusoids remain, and the amplitude of and phase difference between these sinusoids are indicated on front-panel meters. Thus, the 8405A is a tuned voltmeter which responds to the fundamental of the input signal. Voltmeter bandwidth is 1 kHz.

To maintain the converted signals at 20 kHz, the 8405A includes a phase-lock system in channel A which automatically adjusts the period between samples in both channels. In this manner the voltmeter tunes itself to the fundamental of the channel-A input signal. The automatic tuning range is selectable in overlapping bands, each covering at least an octave. Thus, the only manual tuning required is the selection of an octave range which includes the input signal. The automatic tuning not only simplifies operation but enables the 8405A to follow a slowly sweeping signal over octave bandwidths. DC outputs proportional to both amplitude and phase are available on the rear panel for recording purposes.

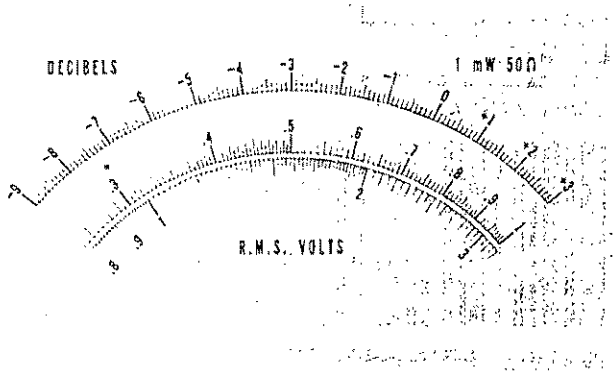
The input signals are applied through convenient ac coupled probes which are permanently attached to the instrument. These probes present a high input impedance (0.1 megohm shunted by 2.5 picofarads), which means that you can use them for monitoring or probing within the system under test with minimum loading effects. Accessories supplied with the voltmeter include 10:1 dividers which attach to the probes. The dividers increase the maximum voltage range to 10 volts and the input impedance to 1 megohm shunted by 2 picofarads. The ac coupling in the probes permits you to measure signals as much as 50 volts off ground.

button phase-finder switch simplifies the setting of the meter offset when the more sensitive phase ranges are selected. A dc output provides a voltage proportional to the linear phase meter reading for either monitoring or expanding resolution on a recorder.

Two-Channel Voltmeter, 100 μV Full-Scale Sensitivity, >90-dB Range

The two-channel input of the 8405A allows you to make repetitive voltage measurements at two points in a circuit. For example, you can check the effects of adjustments without altering the setup. Voltage is read on a single front-panel meter; you measure the voltage in either channel simply by setting a switch.

Voltages from less than 100 microvolts to 1 volt can be measured on channel B of the 8405A, from less than 300 microvolts to 1 volt on channel A. (Channel A requires the higher input to operate the automatic tuning.) External 10:1 dividers are supplied to extend the range of both channels to 10 volts. This wide range, plus the selective 1-kHz bandwidth, enables you to measure gains or losses in excess of 90 dB simply and accurately.



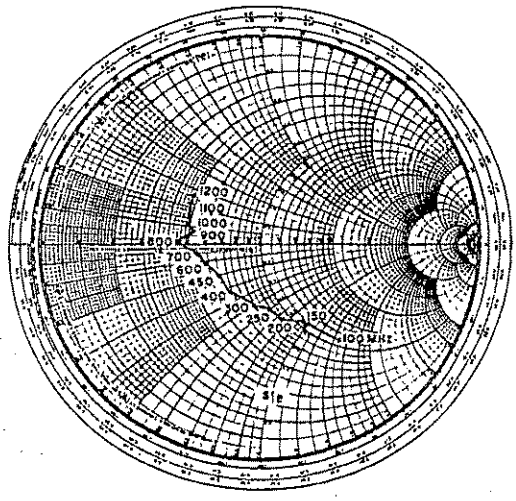
Linear dB scale available on Option 02 version of the 8405A.

Both volt and phase meters have rugged, reliable taut-band suspensions with mirror-backed scales individually calibrated to the meter movement. The voltmeter is optionally available with a linear dB scale uppermost as shown above. This option is particularly well suited to relative measurements such as gain and attenuation as well as applications in which the decibel, rather than the volt, is the primary unit of measurement.

Applications

Complex impedance and transmission parameters

Since the 8405A measures both phase and magnitude, it can be used to fully define the complex transmission and reflection coefficient of two-port networks and components, including transistors. The Smith-chart plot of the input reflection coefficient of a 2N3563 high-frequency transistor is shown below; data was entered on the chart directly from the 8405A voltage and phase readings.

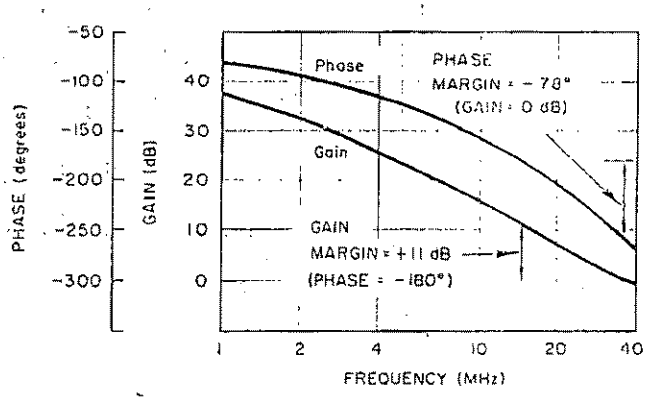


Smith-chart plot of input impedance for a 2N3563, common emitter configuration, from 100 to 1,200 MHz.

For straightforward impedance measurements, the 8405A is easier to use than a slotted line or VHF bridge; reducing the data involves none of the cumbersome calculations and correction factors associated with the slotted line or bridge. The data is easily entered on a Smith chart. With a network or component fully defined, its performance under any given set of conditions can be determined readily.

Feedback circuit design

Design and testing of negative-feedback amplifiers is another important application for the 8405A. Both phase and magnitude frequency response are measured easily. The phase margin at the gain-crossover point is readily determined, and points of marginal stability are easy to locate. The graph below shows data taken from an unstable amplifier. The 8405A can also be used to characterize positive-feedback oscillators.



Open-loop gain and phase shift of a negative-feedback amplifier. As data indicates, amplifier is unstable.