
778D Dual Directional Coupler

Operating and Service
Manual

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Agilent Technologies, Inc.
1400 Fountaingrove Parkway
Santa Rosa, CA 95403-1799, U.S.A.

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United States (tel) 1 800 452 4844	Japan (tel) (+81) 426 56 7832 (fax) (+81) 426 56 7840	New Zealand (tel) 0 800 738 378 (fax) (+64) 4 495 8950	Europe (tel) (+31) 20 547 2323 (fax) (+31) 20 547 2390
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Asia Call Center Numbers

Country	Phone Number	Fax Number
Singapore	1-800-375-8100	(65) 836-0252
Malaysia	1-800-828-848	1-800-801664
Philippines	(632) 8426802 1-800-16510170 (PLDT Subscriber Only)	(632) 8426809 1-800-16510288 (PLDT Subscriber Only)
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People's Republic of China	800-810-0189 (preferred) 10800-650-0021	10800-650-0121
India	1-600-11-2929	000-800-650-1101

Safety and Regulatory Information

Review this product and related documentation to familiarize yourself with safety markings and instructions before you operate the instrument. This product has been designed and tested in accordance with international standards.

WARNING

The **WARNING** notice denotes a hazard. It calls attention to a procedure, practice, or the like, that, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a **WARNING** notice until the indicated conditions are fully understood and met.

CAUTION

The **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a **CAUTION** notice until the indicated conditions are fully understood and met.

Instrument Markings



When you see this symbol on your instrument, you should refer to the instrument's instruction manual for important information.



This symbol indicates hazardous voltages.



The laser radiation symbol is marked on products that have a laser output.



This symbol indicates that the instrument requires alternating current (ac) input.



The CE mark is a registered trademark of the European Community. If it is accompanied by a year, it indicates the year the design was proven.



The CSA mark is a registered trademark of the Canadian Standards Association.

1SM1-A

This text indicates that the instrument is an Industrial Scientific and Medical Group 1 Class A product (CISPER 11, Clause 4).



This symbol indicates that the power line switch is ON.



This symbol indicates that the power line switch is OFF or in STANDBY position.

**Safety Earth
Ground**

This is a Safety Class I product (provided with a protective earthing terminal). An uninterruptible safety earth ground must be provided from the main power source to the product input wiring terminals, power cord, or supplied power cord set. Whenever it is likely that the protection has been impaired, the product must be made inoperative and secured against any unintended operation.

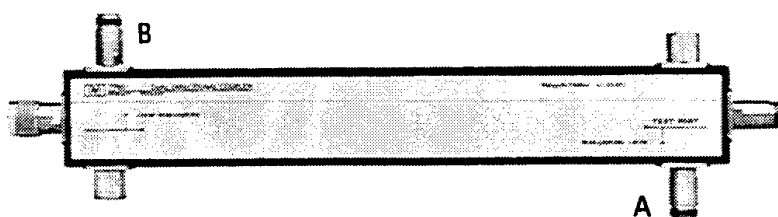
Before Applying Power

Verify that the product is configured to match the available main power source as described in the input power configuration instructions in this manual. If this product is to be powered by autotransformer, make sure the common terminal is connected to the neutral (grounded) side of the ac power supply.

Overview

This coaxial dual directional coupler has a frequency range extending over four octaves from 100 MHz to 2 GHz. Although the coupling factor increases 6 dB/octave below 100 MHz, directivity remains above 36 dB. Thus, the coupler can be used below 100 MHz as well as above. The usefulness below 100 MHz is restricted only by the amount of signal source power and/or the sensitivity of the RF detector connected to the coupler.

The unidirectional characteristic of the Agilent 778D dual directional coupler makes it an important tool in microwave measurement systems. The 778D has the property of inducing, in an auxiliary line, a contra-directional flow of power which is proportional to the power flowing in the main guide. This coupler may be used in the measurement of reflection coefficients or SWR over a very wide frequency range. The relatively constant coupling across several frequency bands and the stability of coupling with time make the 778D useful, also, as a wideband attenuator or for power monitoring applications.



Description

To achieve its broad frequency coverage, the 778D's directivity is optimized for mainline energy flowing in one direction. This means that there is a preferred orientation for the 778D. To achieve the measurement accuracies in the specifications, the test device or system should be connected where the 778D is labeled TEST PORT. To accommodate test devices with Type N or APC-7 connectors, a choice of connectors is available on the TEST PORT (see Options outlined in [“Specifications” on page 2](#)).

With the APC-7 precision sexless connector on the output, the coupler can be conveniently converted to other types of connectors by the use of an adapter. Adapters are available to the SMA (OSM), TNC, GR900, and others, so that the coupler becomes a versatile device for making measurements on many different types of connectors. The Amphenol APC-7 is a sexless connector with very low SWR. This precision connector makes possible the construction of adapters with low SWR.

Specifications

Specifications for the 778D are shown in the following table.

Characteristic	Value
Frequency range	100 to 2000 MHz (usable below 100 MHz)
Directivity	See figure on page 1
Auxiliary arm 0.1 to 1.0 GHz	A 36 dB B 30 dB
Auxiliary arm 1.0 to 2.0 GHz	A 32 dB B 30 dB
Coupling Attenuation	nominal coupling above 450 MHz is 20 dB nominal coupling above 450 MHz is 20 dB increasing with a slope of 0.006 dB/MHz for decreasing frequency.
Coupling variation	±1.5 dB from nominal
Cyclical variation	Frequency is similar to Figure 7 on page 10 . ¹
Tracking	Auxiliary outputs typically track within 0.7 dB. Phase tracking typically 4°.
SWR	Primary Line ≤1.1 Auxiliary Arms ≤1.1
Maximum main line power	50 W average 500 W peak
Accessories available adapters ²	11533A APC-7 to SMA male 11534A APC-7 to SMA female 11525A APC-7 to Type N male 11524A APC-7 to Type N female
Connectors	Choice of main line connectors (see options) Auxiliary Arms have Type N female All Type N connectors stainless steel, compatible with MIL-C-39012 and MIL-C-71.
Dimension	16-3/4 in long x 4-3/8 in high x 1-3/16 in wide (425 mm x 111 mm x 30 mm)
Net weight	3-3/4 lb (1.5 kg)
Options available	778D (Type N female output, Type N male input connectors) Option 011 (APC-7 output, Type N female input connectors) Option 012 (Type N male output, Type N female input connectors)

1. See [Figure 6 on page 8](#) for a typical coupling curve.

2. Adapters from APC-7 to TNC, GR-900, GR-874 as well as the above are available from Amphenol RF Division, Danbury, CN)

Installation and Shipping

Unpacking and Inspection

The coupler was carefully inspected mechanically and electrically prior to shipment. Inspect it for mechanical damage incurred in transit, and test electrical performance using the test procedure given under Performance Testing. If there is damage or deficiency, notify the carrier and the nearest Agilent Technologies office. In the event of mechanical damage, the packing materials and carton should be held for the carrier's inspection.

CAUTION

Protect the face of the connectors (especially the APC-7) from damage. Any scoring or burring of the mating surfaces causes discontinuity; the resulting increase in SWR degrades performance (see [Figure 1](#)).

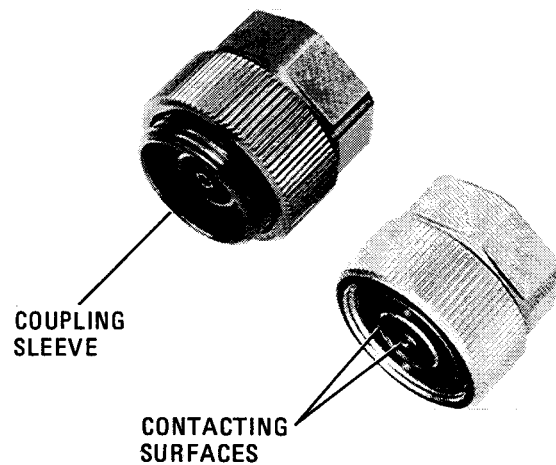


Figure 1 Care of APC-7 Connectors

Repackaging for Shipment

Using Original Packaging

The same containers and materials used in factory packaging can be obtained through Agilent Technologies.

If the coupler is being returned to Agilent Technologies for servicing, attach a tag indicating the type of service required, return address, and model number. Also, mark the container *FRAGILE* to assure careful handling.

In any correspondence refer to the coupler by full model number.

Using Other Packaging

The following general instructions should be used for repackaging with commercially available materials:

1. Wrap the coupler in heavy paper or plastic. (If shipping to a Agilent Technologies office or service center, attach a tag indicating the type of service required, return address, and model number.)
2. Use a strong shipping container. A double wall carton made of 2.4 MPa (350 psi) test material is adequate.
3. Use enough shock-absorbing material (3-4-inch layer) around all sides of the coupler to provide firm cushion and prevent movement inside the container.
4. Seal the shipping container securely.
5. Mark the shipping container *FRAGILE* to assure careful handling.

Load-Bearing

When installing be sure auxiliary equipment supports its own weight. The coupler, particularly the connectors, is not designed to carry weight. Load limits for APC-7 connectors are given in [Figure 2](#).

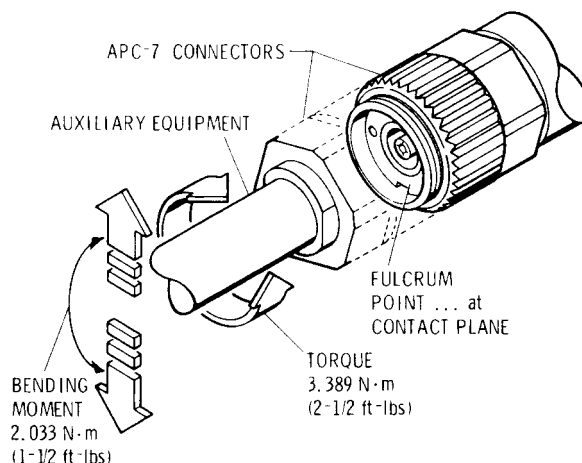


Figure 2 Load Limits for APC-7 Connector

Operation

Signal Flow

Unlike some other dual-directional couplers, this coupler is polarized. For best performance the signal must flow through the coupler as shown in [Figure 3](#). Observe the TEST PORT designation on the label. DO NOT reverse the coupler since the directivity may be somewhat lower in the reverse direction. To test devices with other types of connectors, another coupler with the correct mating test port connector is recommended. Using an adapter will degrade the effective directivity of the measurement.

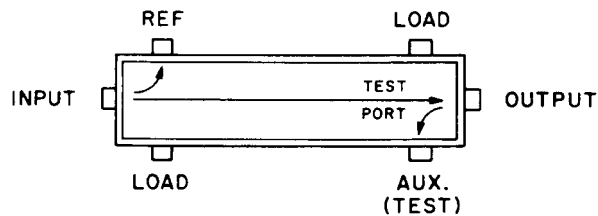


Figure 3 Signal Flow

Coupler Temperature

Operate the coupler at normal room temperature and do not temperature cycle the coupler in use or storage. Heat cycling may degrade the performance of the coupler.

Reflectometer Measurements

[Figure 4 on page 6](#) shows an arrangement in which swept-frequency measurements of reflection coefficient are easily made with the coupler. Incident and reflected signals are detected from the auxiliary arms of the coupler. The signals can then be displayed on an oscilloscope or X-Y recorder to give a visual display of reflection coefficient or SWR.

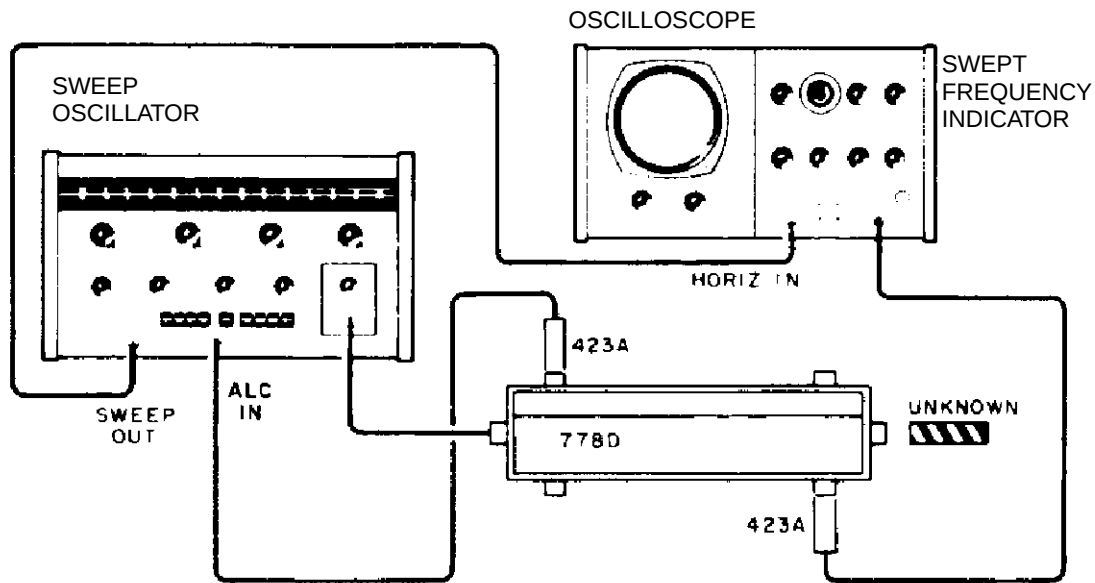


Figure 4 Typical Reflectometry Setup

The high directivity and close tracking of the auxiliary arms of this coupler make it particularly useful for this type of broadband measurement. The high directivity insures accurate measurements by a true separation of the forward and reflected signals. Close tracking of signal variation from the auxiliary arms gives a flat frequency response that makes readings easy to interpret.

Errors

Maximum errors in reflection measurement due to the coupler are as follows, where Γ_L = reflection coefficient of device under test:

$$\text{Maximum phase error} = \pm \sin^{-1} (\Delta \Gamma_L / \Gamma_L)^\circ (\angle \leq 90^\circ)$$

Table 1 Errors

Frequency Range (GHz)	Maximum Magnitude Error Δ_L	
	Swept Frequency	Fixed Frequency
0.1 to 1	$\pm(0.015+0.04 \Gamma_L +0.05 \Gamma_L ^2)$	$\pm 0.015+0.05 \Gamma_L ^2$
1 to 2	$\pm(0.025+0.04 \Gamma_L +0.05 \Gamma_L ^2)$	$\pm 0.025+0.05 \Gamma_L ^2$

Γ_L = reflection coefficient of unknown.

Errors include directivity, tracking, and source match errors but do not include any detection errors. They are also based on the following conditions: auxiliary arms are terminated in matched loads (VSWR ≤ 1.2). the mean of open- and short- circuit readings is set to 1.0, and the short-circuit phase reading is measured over a band of frequencies and the mean is set to 180°.

Impedance Measurement

The 778D is also well suited for measurements of impedance when used with the Agilent 8508A vector voltmeter (see [Figure 5](#)). Again, a reflectometry technique is used. With the vector voltmeter, however, both magnitude and phase of the reflection coefficient can be measured.

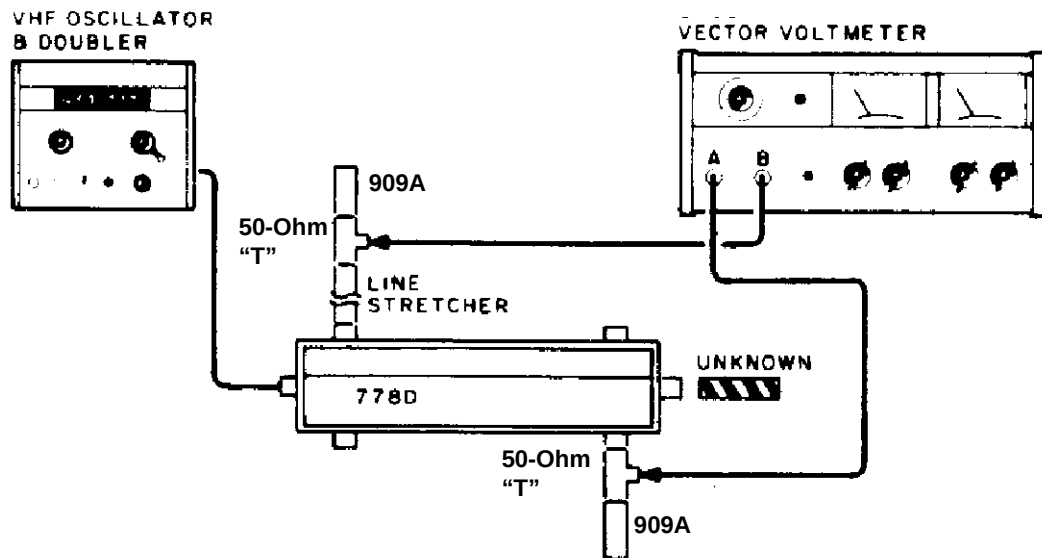


Figure 5 Setup for Impedance Measurement

Data can be read from the two meters of the vector voltmeter and transferred directly to a Smith Chart to provide impedance information of such devices as antennas or other passive components. In addition, with an appropriate bias supply, active components, such as transistors, can also be quickly measured and their characteristics determined with this setup. The 778D is well suited for these types of measurements since both the phase and magnitude variation between the coupling arms have been closely controlled in the design of the coupler.

Power Leveling

The 778D has cyclic coupling variations of up to ± 2 dB. For this reason it is not recommended for power leveling that requires flatness exceeding these tolerances. A typical coupling curve is shown in [Figure 7 on page 10](#).

Maintenance

The directional coupler should need very little maintenance besides keeping it clean and protecting the connector faces.

Operation

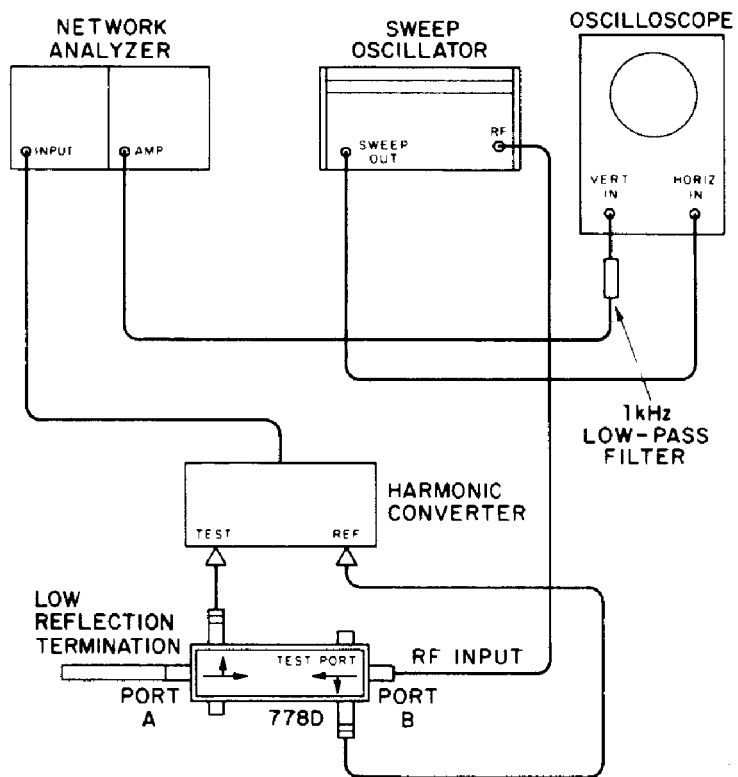


Figure 6 Typical Coupling Variation with Frequency

Performance Testing

Use the following procedure for initial inspection, performance testing, or whenever the coupler performance is suspected. [Table 2](#) lists equipment necessary for testing. Other equipment may be substituted provided its specifications equal or exceed the specifications listed under Critical Specifications. The coupler should be tested on a swept-frequency basis to assure that there are no out-of-specification narrow-frequency bands between the spot frequencies tested on a fixed-frequency basis. If the results of swept-frequency testing are doubtful or if the equipment for swept-frequency testing is not available, the fixed-frequency test may be used. [Table 3 on page 11](#) provides a place to record the results.

Table 2 *Recommended Test Equipment*

Instrument	Critical Specifications
Sweep oscillator	Frequency: 0.1 to 2.0 GHz Modulation: 1kHz square wave Leveling: —V proportional to RF
Low-pass filter	Rejects: second harmonics lowest frequency Rejection: ≥ 50 dB at $1.25 f_{co}$
Network analyzer	No other network analyzer is recommended
SWR meter	Frequency: compatible with sweep oscillator Accuracy: ± 0.1 dB
X-Y recorder	Impedance: 200 K ohms/V Sensitivity: ≥ 50 mV/in
Crystal detector (2)	Frequency: 0.1 to 2.0 GHz Sensitivity: > 4.0 mV / μ W
Coaxial attenuator	Frequency: 0.1 to 2.0 GHz Attenuation: 20 dB or 10 dB
Low reflection termination	SWR: ≤ 1.005 0.1 MHz to 2.0 GHz Type N connectors
Oscilloscope	Vertical Sensitivity: > 10 mV/cm Horizontal Sweep: synchronized ext
Termination (2)	Frequency: band of interest Load SWR: < 1.01 , de to 2 GHz
Dual directional coupler	Frequency: band of interest Directivity: > 40 dB Impedance: 50 ohms coaxial
Short	7 mm coaxial Type N

Table 2 *Recommended Test Equipment (Continued)*

Instrument	Critical Specifications
Adapter (2)	Type N male to male
1 kHz Filter Adapter	Rejects 1 kHz and above

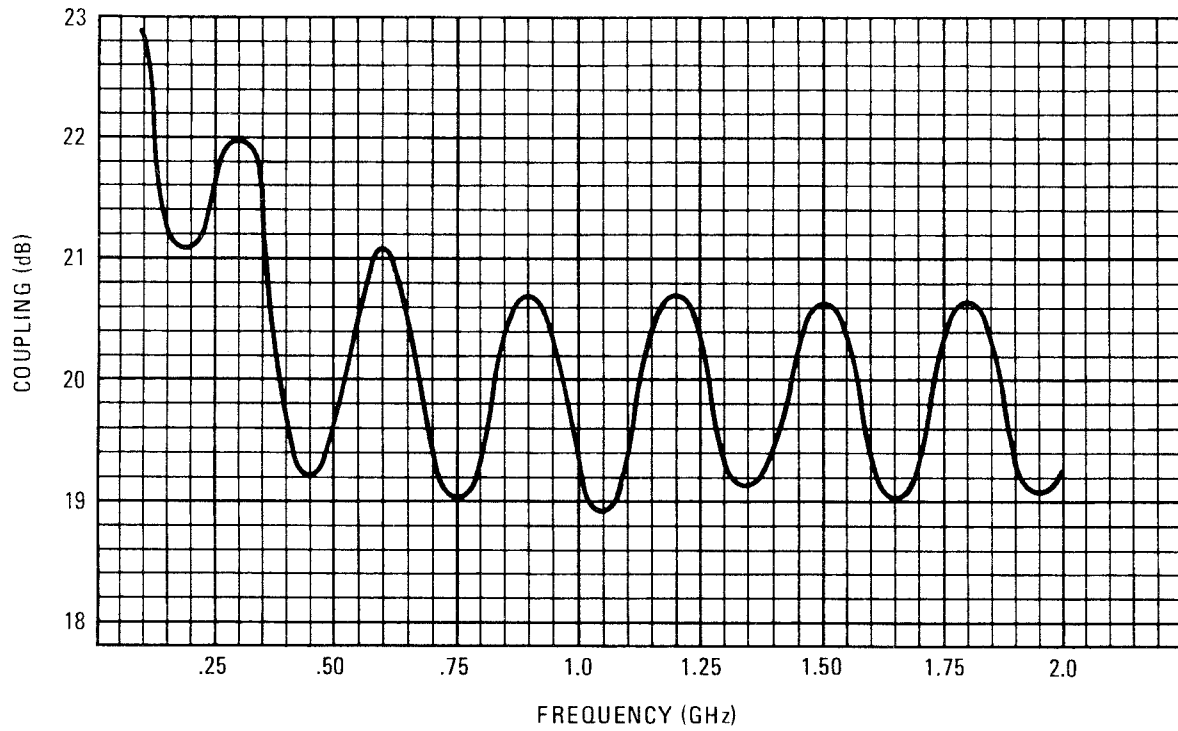
**Figure 7** *Typical Coupling Variation with Frequency*

Table 3 Performance Test Record

Tested by:		
Date:		
Dual-Directional Coupler:		
Instrument Serial Number:		
Directivity:		
Auxiliary Arm:	0.1 to 1.0 GHz	1.0 to 2.0 GHz
A	_____ dB (≤ -36 dB)	_____ dB (≤ -32 dB)
B	_____ dB (≤ -30 dB)	_____ dB (≤ -30 dB)
SWR Measurement		
Primary Line	_____ (≤ 1.1)	_____ (≤ 1.1)
Auxiliary Arm	_____ (≤ 1.1)	_____ (≤ 1.1)

Swept-Frequency Directivity

Directivity (in dB) is equal to:

$$10 \log \frac{(P_{aux}) \text{ when Pmain flows forward}}{(P_{aux}) \text{ when Pmain flows reversed}}$$

where

P = Power
aux = auxiliary arm
main = main arm

NOTE

The power input to the main arm is the same for both measurements.

To measure the directivity proceed as follows:

1. Connect the equipment as shown in [Figure 8 on page 12](#) (the purpose of the 1 kHz low-pass filter input to the oscilloscope is to reduce noise).

Performance Testing

The setup as shown will measure the directivity of port A. To measure the directivity of port B reverse the coupler.

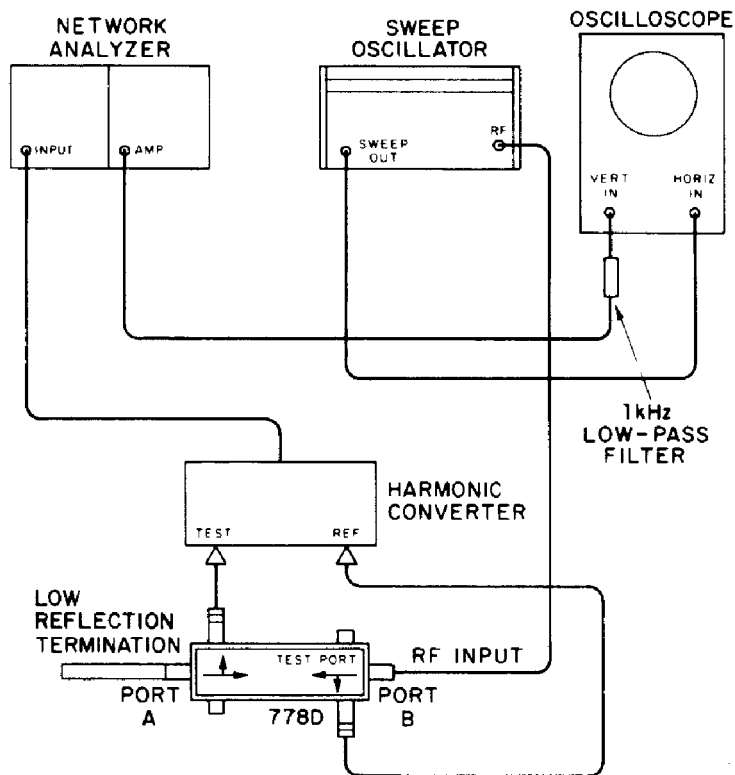


Figure 8 Swept-Frequency Directivity Setup

- Set the controls as shown in [Table 4 on page 12](#).

Table 4 Control Settings

Characteristic	Setting
Network Analyzer	
Frequency range	1 to 2 GHz (set Sweep Stability Vernier to phase lock display)
Amplitude (test Channel Gain)	20 dB
Sweep Oscillator (see network analyzer manual for proper output level).	
Function	Start-Stop
Start/CW	1.0 GHz
Stop/ Δ F	2.0 GHz
Sweep Selector	Auto
Sweep Time	1.0–0.1 (set vernier to phase lock display)

Table 4 Control Settings (Continued)

Characteristic	Setting
Vertical Sens	50 mV, calibration to make 1 dB gain change on network analyzer equal 1 cm vertical change on CRT
Horizon Sens	1 V/cm
Sweep Mode	Ext
Input	DC

3. To establish a reference remove the low reflection termination. This open will give a condition of 100% reflection. If a good short is available use also and take the amplitude reference as the average between the shorted and open conditions.
4. Be sure network analyzer is phase locked over entire range. The display on the oscilloscope should be an unbroken line. If not, adjust network analyzer SWEEP STABILITY and/or AMPLITUDE controls to phase lock over the entire sweep.
5. Zero network analyzer phase gain meter on 10 dB AMPLITUDE range with AMPL VERNIER control or AMPLITUDE TEST CHANNEL GAIN (dB).
6. Draw a horizontal line with a grease pencil on the CRT somewhere above the middle X-axis line.
7. Place the average of the reference trace on the grease pencil line by adjusting the oscilloscope VERTICAL POSITION control.
8. Put the low reflection termination back on the coupler as shown in [Figure 8](#).
9. Increase the network analyzer TEST CHANNEL GAIN (DB) by the amount of the directivity specification for this frequency range.
10. The entire trace should stay below the grease pencil line. If a portion of the trace goes above the line the coupler may or may not be out of specification (the reflection from the load may be adding to the directivity of the coupler). Test these ambiguous frequencies with the fixed frequency testing following.
11. Repeat this test at the other frequency range given in the [“Specifications” on page 2](#). Then turn the coupler around to test the directivity at port B and repeat the above tests.

Termination

In the preceding of the following tests use the best termination obtainable. The accuracy of the tests will depend to a great extent upon the quality of the termination. Note that the quality of the termination includes any adapter necessary for connection. The adapter reflection coefficient will add vectorially to the termination reflection coefficient. These instructions assume the use of a termination with a total SWR of 1.005 or less.

SWR Measurement

SWR in this procedure will be measured in terms of reflection coefficient. Because the directional couplers used in this procedure have finite directivity, the measurement error due to directivity is taken into consideration in determining the test limits.

1. Connect the equipment as shown in [Figure 9](#).

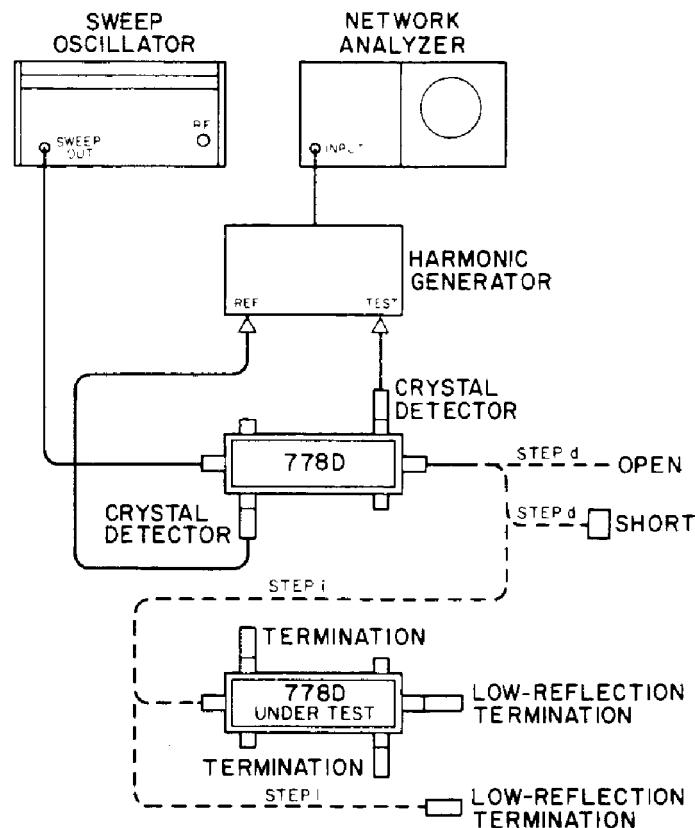


Figure 9 SWR Measurement Setup

2. Set controls as shown in [Table 4 on page 12](#).
3. Set sweep oscillator to sweep an octave band in the range 0.1 to 2 GHz with no modulation.
4. To establish a reference, remove the termination. This open will give a condition of 100% reflection. If a good short is available, use it also and

take the amplitude reference as the average between the shorted and open conditions.

5. Be sure network analyzer is phase locked over entire range. The display on the polar display should be an unbroken circle. If not, adjust network analyzer SWEEP STABILITY and/or AMPLITUDE controls to phase lock over the entire sweep.
6. Push and hold the polar display's BEAM CTR push button and adjust HORIZ POS and VERT POS controls to place the dot in the center of the graticule. To bring the dot onto the display, rotate each positioning control about five turns counterclockwise or until a slight increase in resistance to movement is encountered. Then turn each control two and one-half turns clockwise.
7. Center the trace on the outer graticule circle, using the network analyzer position and amplitude controls. If a good short is available, average the position between the open and shorted indications. Note TEST CHANNEL GAIN reading.
8. Increase TEST CHANNEL GAIN by 26 dB. The outer graticule is now calibrated to a reflection coefficient of 0.05 and the inner graticule to 0.01.
9. Connect the mainline of the 778D under test in place of the termination shown in [Figure 9](#). Terminate the mainline of the 778D under test with the best termination available. A poorer termination may be used to terminate the auxiliary arms.
10. The indication should be less than the following limits:
0.1 to 1.0 GHz: 0.032
1.0 to 2.0 GHz: 0.022
11. If these limits are exceeded at any frequency, set the sweep oscillator for CW operation at this frequency.
12. Remove the 778D under test from the reflectometer and connect a low-reflection termination to the reflectometer.
13. With the VERT and HORIZ Position controls set the dot to the center of the graticule. This effectively cancels out the directivity signal at this frequency.
14. Remove the low-reflection termination and reconnect the 778D under test. The indication should be less than 0.045 (0.1 to 2.0 GHz).