Directional Couplers and Bridges

Applications

Directional couplers[1] are general purpose tools used in RF and microwave signal routing for isolating, separating or combining signals. They find use in a variety of measurement applications:

- Power monitoring
- Source leveling
- Isolation of signal sources
- Swept transmission and reflection measurements

Key Specifications

The key specifications for a directional coupler depend on its application. Each of them should be carefully evaluated to ensure that the coupler meets its intended use.

- Directivity
- SWR
- Coupling coefficient
- Transmission loss
- Input power

Directivity

Directivity is a measure of how well the coupler isolates two opposite-travelling (forward and reverse) signals. In the case of measuring reflection coefficient (return loss) of a device under test, directivity is a crucial parameter in the uncertainty of the result. Figure 1 shows how the reflection signal, E_r, is degraded by the undesired portion of the incident signal D_2. And since the undesired signal, D_2, combines with the reflected signal as a phasor, the error in the measured signal E_{m2} can only be compensated or corrected on a broadband basis using vector analyzers.

[1] See Waveguide chapter for additional products.

Because the reverse-coupled signal is very small, it adds a negligible amount of uncertainty when measuring large reflections. But as the reflected signal becomes smaller, the reverse-coupled signal becomes more significant.

For example, when the return loss in dB equals the value of directivity, the measurement error can be between -6 to +8 dB. The higher the directivity specified in dB, the higher the measurement accuracy. The effect of the directivity error on the forward-coupler output, E_{m1}, is less important because the desired signal is usually a large value. When HP couplers are used for power monitoring and leveling, directivity is less important than coupling coefficient flatness.

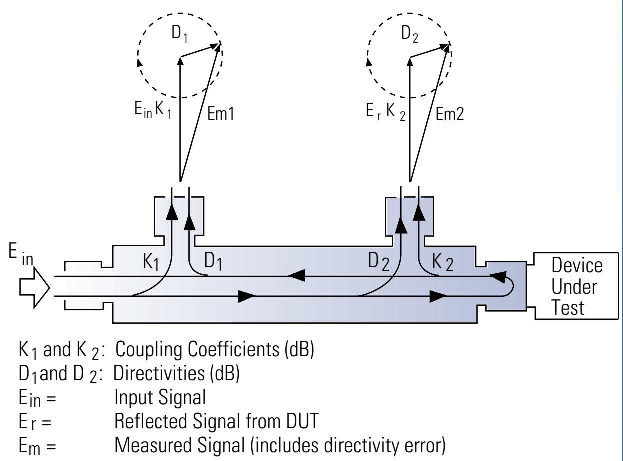


Figure 1.
Effect of directivity on reflection measurement.

SWR

For many applications, coupler SWR is important to minimize low mismatch errors and to improve measurement accuracy. For example, when making swept reflection measurements, it is customary to set a full reflection (0 dB return loss) reference by connecting a short at the test port of the coupler. Some of the reflected signal re-reflects due to the output port (test port) SWR. This re-reflected signal goes through a wide phase variation because of the width of the frequency sweep, adding to and subtracting from the reflected signal. This phase variation creates a ripple in the full reflection (0 dB return loss) reference. The magnitude of the re-reflected signal, and thus the measurement uncertainty, can be minimized by selecting couplers with the lowest SWR.

Coupling Coefficient

In power monitoring and leveling, the most desired specification is a highly accurate and flat coupling value, because the coupling factor directly affects the measurement data. For wideband leveling, the coupling factor directly influences the flatness of the output power. Coupling values of 10 and 20 dB are most common but for high power and pulsed systems, there can be a need for 40 dB coupling.

In reflection measurements, coupling factor is less important than directivity and SWR, since both the forward and reverse coupling elements are usually identical, and so the variation of coupling factors match versus frequency.

Transmission Loss

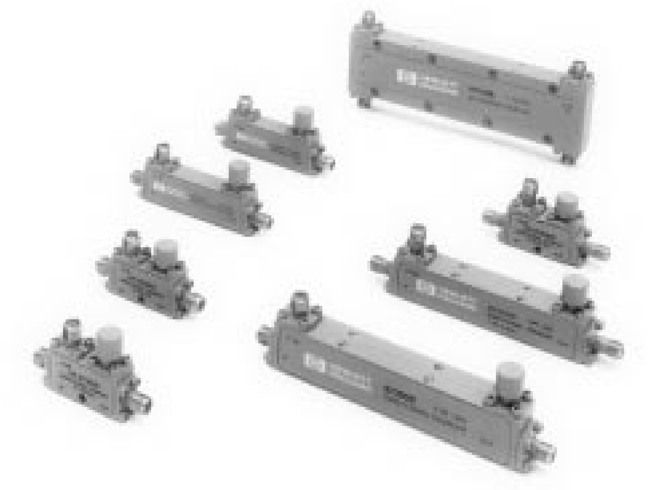
Transmission loss is the total loss in the main line of a directional coupler, and includes both insertion loss and coupling loss. For example, for a 10 dB coupler, 10% of the forward signal is coupled off, which represents approximately 0.4 dB of signal loss added to the inherent losses in the main transmission line.

Transmission loss is usually not important at low frequencies where most swept sources have sufficient available power. However, in the millimeter ranges, power sources are limited and lower loss devices become significant. In general, broadband couplers have transmission losses on the order of 1 dB. On the other hand, directional bridges, which are sometimes used in place of couplers for reflection/transmission measurements, have insertion losses of at least 6 dB. This loss directly subtracts from the dynamic range of the measurement.

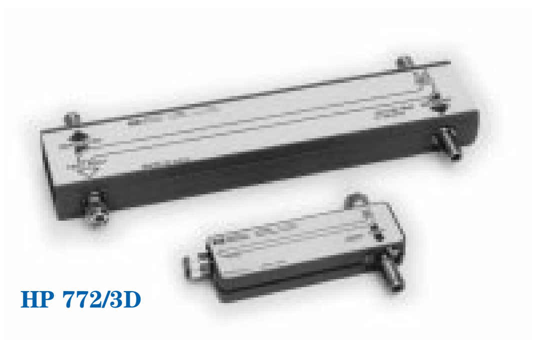
Input Power

High power handling characteristics of directional couplers are critical when used for monitoring pulsed power systems. Most couplers designed for test and measurement applications are not ideal for system powers in the kilowatt range. One reason is that the coupler's secondary transmission line often has an internal termination that limits the coupler's mainline power handling capability. A second reason is the maximum power rating of the connectors. Such models have a power rating from 20 to 50 W average.

Single- and Dual-Directional Couplers, 90° Hybrid Coupler



HP 87300/301 Series, 87310B



HP 772/3D

HP 87300/301 Series Directional Couplers

This line of compact, broadband directional couplers is ideal for signal monitoring, or, when combined with a coaxial detector, for signal leveling. The HP 8474 series coaxial detectors are recommended if output detection is desired. A broad offering of products is available with frequencies up to 50 GHz.

HP 87310B Hybrid Coupler

The HP 87310B is a 3 dB hybrid coupler, intended for applications requiring a 90 degree phase difference between output ports. In that sense, it is different from typical power dividers and power splitters, which have matched signal phase at their output ports.

HP 773D Directional Coupler
HP 772D Dual-Directional Coupler

These high-performance couplers are designed for broadband swept measurements in the 2 to 18 GHz range. The HP 773D is ideal for leveling broadband sources when used with an HP 8474B detector. (Also, see the HP 83036C directional detector). For reflectometer applications, the HP 772D dual coupler is the best coupler to use with HP power sensors and power meters (such as the HP 438A dual power meter). Forward and reverse power measurements on transmitters, components, or other broadband systems are made simpler by using the HP 772D.

The broadband design allows the use of a single test setup and calibration for tests spanning the entire 2 to 18 GHz frequency range.

Single- and Dual-Directional Couplers, 90° Hybrid Coupler

HP 775D

HP 775D-778D Dual-Directional Couplers

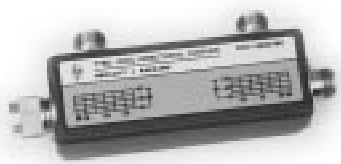
These couplers cover a frequency spread of more than 2:1, each centered on one of the important VHF/UHF bands. HP 778D covers a multi-octave band from 100 to 2000 MHz. With their high direc- tivity and mean coupling accuracy of ±0.5 dB, these are ideal couplers for reflectometer applications. Power ratings are 50 W average, 500 W peak.

HP 779D Directional Coupler

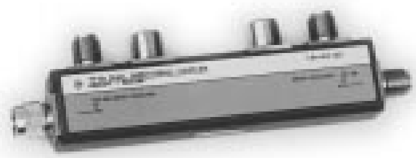
This high directivity coupler has a multi-octave range of 1.7 to 12.4 GHz. With directivity over 30 dB to 4 GHz and 26 dB to 12.4 GHz, it is useful for broadband reflectometer measurements. With ±0.75 dB coupling variation, the coupler is also useful for power leveling applications. Optional connectors provide flexibility in mating with various devices under test.

HP 11691D and 11692D Directional Couplers

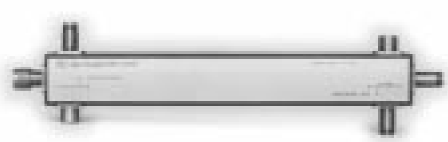
HP 11691D is a single coupler for 2 to 18 GHz with a 20 dB coupling factor. With 30 dB directivity to 8 GHz and 26 dB to 18 GHz, it is useful for broadband reflectometry. It features many connector options to match test device requirements. HP 11692D is a dual-directional coupler with the same performance specifications as the HP 11691D. The dual couplers make it possible to measure both reflection and transmission parameters of a device under test at one time.



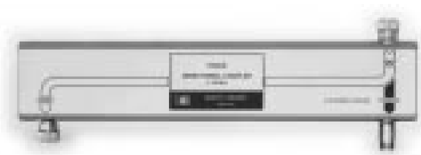
HP 776D



HP 777D

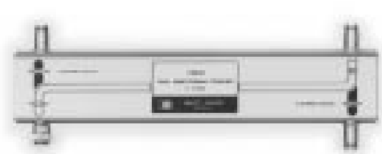


HP 778D



HP 11691D

HP 779D



HP 11692D

Single- and Dual-Directional Couplers, 90° Hybrid Coupler

Specifications [1]

HP Model	Frequency Range (GHz)	Nominal Coupling & Variation (dB)	Directivity (dB)	Maximum SWR	Insertion Loss (dB)	Power Rating Average, Peak
87300B	1 to 20	10±0.5	>16	1.35	<1.5	20 W, 3 kW
87300C	1 to 26.5	10±1.0	>14 to 12.4 GHz >12 to 26.5 GHz	1.35 to 12.4 GHz 1.5 to 26.5 GHz	<1.2 to 12.4 GHz <1.7 to 26.5 GHz	20 W, 3 kW
87300C Option 020	1 to 26.5	20±1.0	>14	1.4	<1.2	20 W, 3 kW
87300D	6 to 26.5	10±0.5	>13	1.40	<1.3	20 W, 3 kW
87301B	10 to 46	10±0.7	>10	1.80	<1.9	20 W, 3 kW
87301C	10 to 50	10±0.7	>10	1.80	<1.9	20 W, 3 kW
87301D	1 to 40	13±1.0	>14 to 20 GHz >10 to 40 GHz	1.5 to 20 GHz 1.7 to 40 GHz	<1.2 to 20 GHz <1.9 to 40 GHz	20 W, 3 kW
87301E	2 to 50	10±1.0	>13 to 26.5 GHz >10 to 50 GHz	1.5 to 26.5 GHz 1.8 to 50 GHz	<2.0	20 W, 3 kW
772D [2]	2 to 18	20±0.9	>30 to 12.4 GHz >27 to18 GHz	1.28 to12.4 GHz 1.4 to 18 GHz	<1.5	50 W, 250 W
773D [2]	2 to 18	20±0.9	>30 to 12.4 GHz >27 to 18 GHz	1.2	<0.9	50 W, 250 W
775D [3]	0.45 to 0.94	20±1	>40	1.15	<0.40	50 W, 500 W
776D [3]	0.94 to 1.9	20±1	>40	1.15	<0.35	50 W, 500 W
777D [3]	1.9 to 4	20±0.4	>30	1.2	<0.75	50 W, 500 W
778D	0.1 to 2	20±1.5	>36 to 1 GHz[4] >32 to 2 GHz[4]	1.1	<0.60	50 W, 500 W
779D	1.7 to 12.4	20±0.75	>30 to 4 GHz >26 to 12.4 GHz	1.2[5]	<0.60	50 W, 500 W
11691D	2 to 18	20±1.0	>30 to 8 GHz >26 to 18 GHz[6]	1.2[5]	<2.0	50 W, 250 W
11692D	2 to 18	20±1 incident to test port	>30 to 8 GHz >26 to 18 GHz[6]	1.3 to 12.4 GHz 1.4 to 18 GHz	<1.5	50 W, 250 W

[1] See page 66 for connector types.
[2] See data sheet for typical out of band data from 0.1 to 2 GHz and 18 to 20 GHz.
[3] Maximum auxiliary arm tracking: 0.3 dB for HP 776D; 0.5 dB for HP 777D.
[4] 30 dB to 2.0 GHz, input port.
[5] Apparent SWR at the output port of a coupler when used in a closed-loop leveling system.
[6] 24 dB with Type-N connector on the test port.

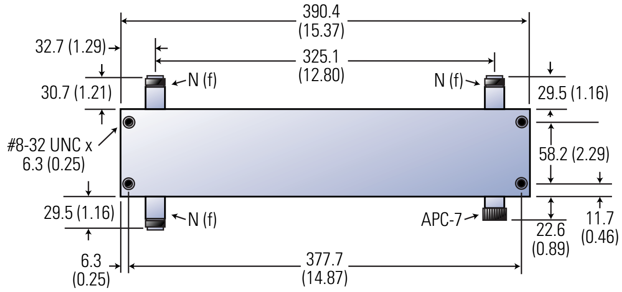
HP 87310B Specifications

Frequency Range	1 to 18 GHz
Coupling	3 dB
Amplitude Imbalance	±0.5 dB at each port, centered at -3 dB
Phase Imbalance	±10 Degrees
Isolation	>17 dB
Maximum SWR	1.35
Insertion Loss	<2.0 dB
Power Rating	
Average	20 W
Peak	3 kW
Connectors	SMA (f)
Weight in Grams (oz)	148 (5.2)

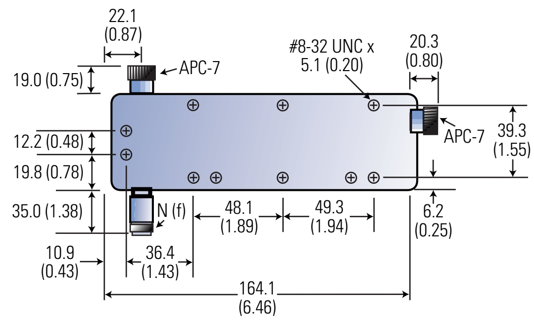
Single- and Dual-Directional Couplers, 90° Hybrid Coupler

Outline Drawings

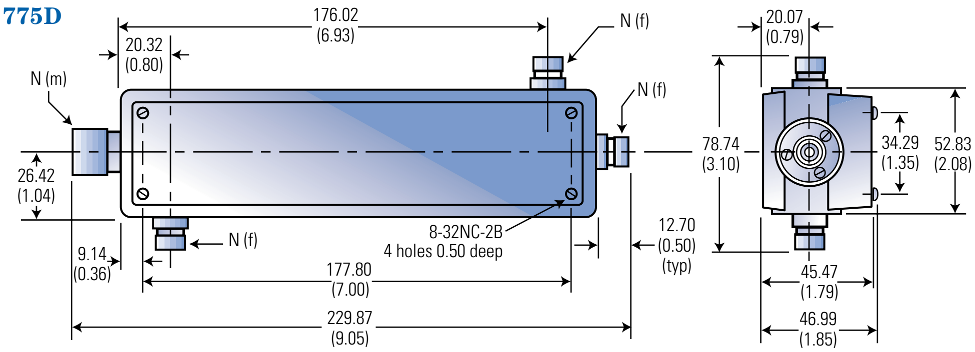
HP 772D



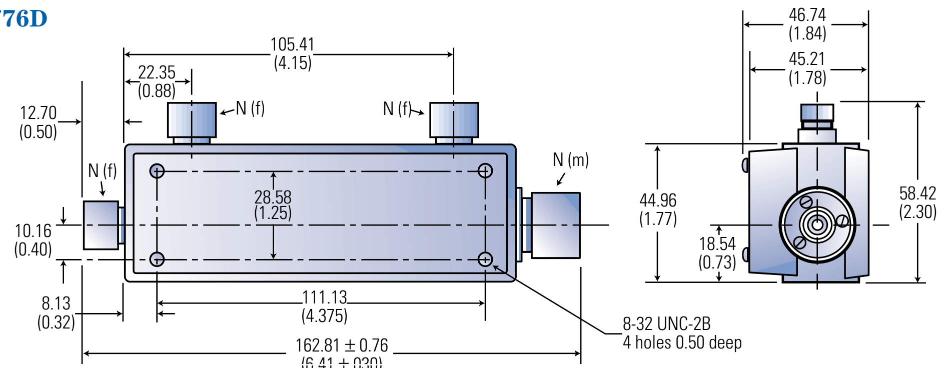
HP 773D



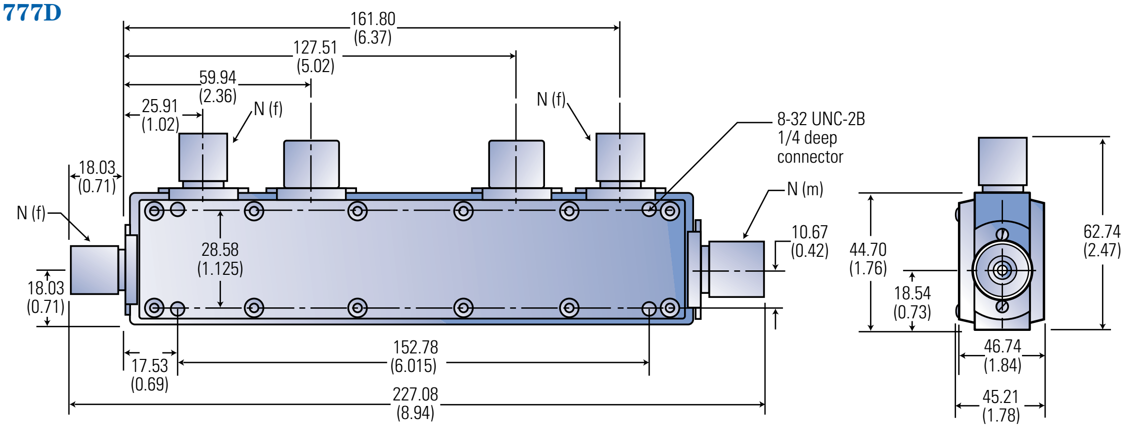
HP 775D



HP 776D



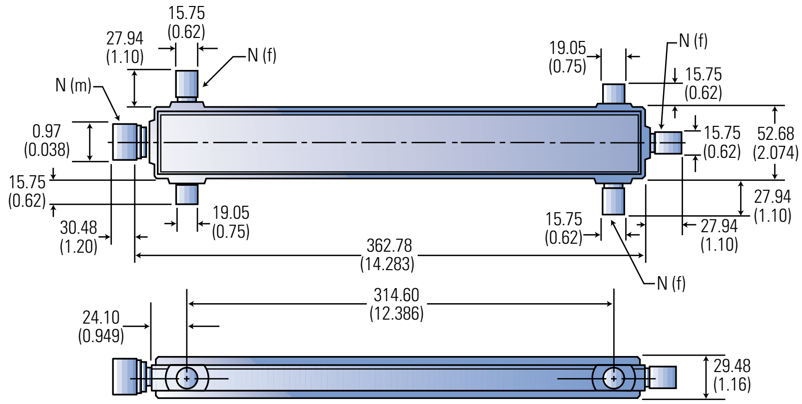
HP 777D



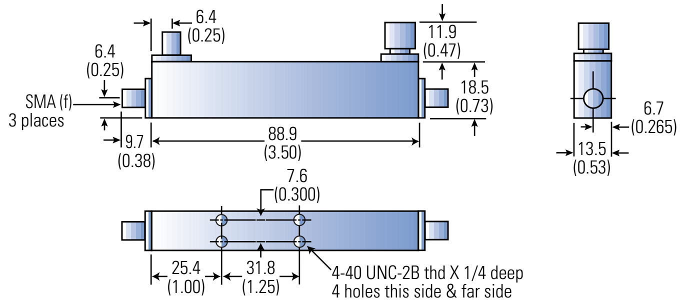
Dimensions are in mm (inches) nominal, unless otherwise specified.

Single-and Dual-Directional Couplers, 90° Hybrid Coupler

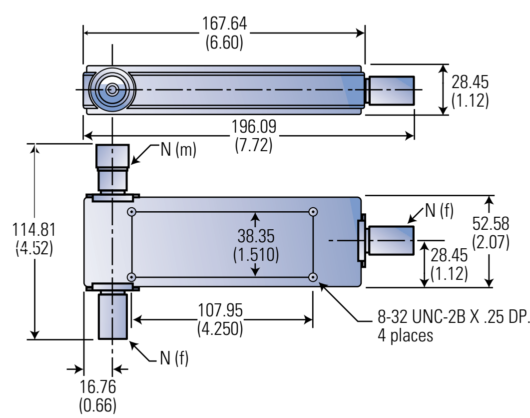
HP 778D



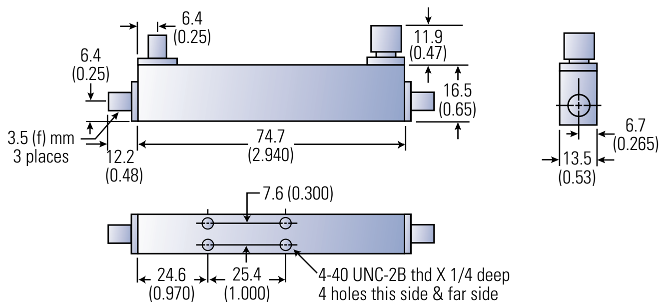
HP 87300B



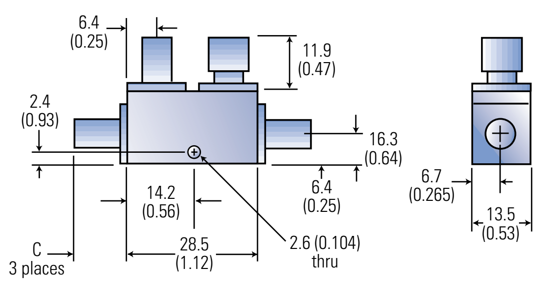
HP 779D



HP 87300C



HP 87300D, 87301B, 87301C

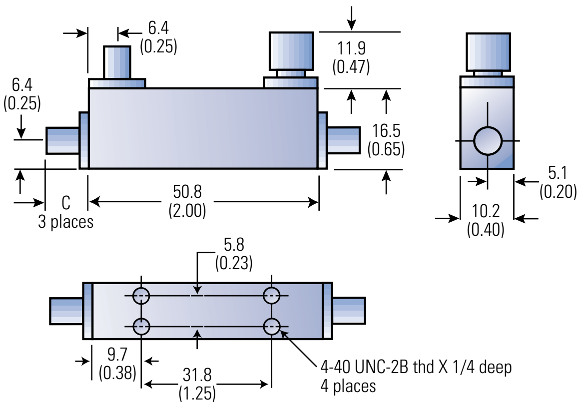


HP Model	Connector Type	C Dimension
87300D	3.5 mm (f)	12.2 (0.48)
87301B	2.9 mm (f)	9.7 (0.38)
87301C	2.4 mm (f)	28.4 (1.0)

Dimensions are in mm (inches) nominal, unless otherwise specified.

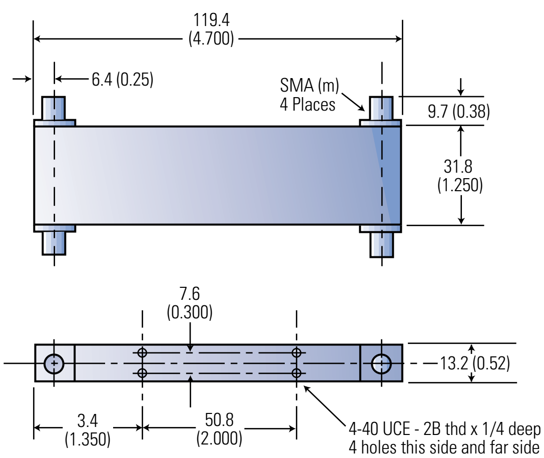
Single- and Dual-Directional Couplers, 90° Hybrid Coupler

HP 87301D,E



Connector Type	C Dimension
2.4 mm (f)	9.7 (0.38)
2.92 mm (f)	9.7 (0.38)

HP 87310B



HP Model	Standard Connectors and Options
772D	Primary line: APC-7, APC-7
	Auxiliary arms: N (f)
Option 001	All N (f)
773D	Primary line: APC-7, APC-7
	Auxiliary arms: N (f)
Option 001	All N (f)
775D -777D	Primary line: N (m), N (f)
	Auxiliary arms: N (f), N (f)
778D	Primary line: N (f), N (m)
	Auxiliary arms: N (f), N (f)
Option 011	Primary line: APC-7, N (f)
Option 012	Primary line: N (m), N (f)
779D	Primary line: N (m) input, N (f) output
	Auxiliary arm: N (f)
Option 010	Primary line: N (f) input, N (m) output
	Auxiliary: N (f)
11691D	Primary: APC-7, APC-7, Auxiliary: N (f)
Option 001	All N (f)
Option 002	Primary: N (f), N (m), Auxiliary: N (f)
Option 003	Primary: N (f), APC-7, Auxiliary: N (f)
Option 004	Primary: N (f), APC-7, Auxiliary: APC-7
Option 005	All APC-7
11692D	Primary: N (f), APC-7, Auxiliary: N (f), N (f)
Option 001	Primary: N (f), N (f) Auxiliary: N (f), N (f)
Option 002	Primary: N (f), N (m) Auxiliary: N (f), N (f)
Option 003	Primary: N (f), APC-7, Auxiliary: APC-7, APC-7
Option 004	All APC-7
87300B	SMA (f), SMA (f), SMA (f)
87300C	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
Option 020	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
87300D	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
87301B	2.92 mm (f), 2.92 mm (f), 2.92 mm (f)
87301C	2.4 mm (f), 2.4 mm (f), 2.4 mm (f)
87301D	2.4 mm (f), 2.4 mm (f), 2.4 mm (f),
Option 292	2.92 mm (f), 2.92 mm (f), 2.92 mm (f)
87301E	2.4 mm (f), 2.4 mm (f), 2.4 mm (f)
87302C	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
87303C	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
87304C	3.5 mm (f), 3.5 mm (f), 3.5 mm (f)
87310B	SMA (m), SMA (m), SMA (m)

Dimensions are in mm (inches) nominal, unless otherwise specified.

Directional Couplers and Bridges

RF Bridges

These high directivity RF bridges are ideal for accurate reflection measurements and signal-leveling applications. They combine the directivity and broadband frequency range of directional bridges and the low insertion loss and flat coupling factor of directional couplers. These bridges can be used with the HP 8711A RF scalar network analyzer, the HP 8753 family of RF vector analyzers as well as HP spectrum analyzers.

HP 86205/207A

HP 86205A

This 50 ohm bridge offers high directivity and excellent port match from 300 kHz to 6 GHz. Directivity is 30 dB to 3 GHz. Coupling factor is 16 dB with a slope of +0.15 dB per GHz to 3 GHz. Insertion loss is 1.5 dB with a slope of +0.1 dB per GHz. Connectors are type-N (f).

HP 86207A

This 75 ohm type-N bridge has high directivity and excellent port match from 300 kHz to 3 GHz. It is used for external reflection measurements or coupling signal from main path. Directivity is 30 dB to 5 MHz, 40 dB to 1.3 GHz, 35 dB to 2 GHz, and 30 dB to 3 GHz. Coupling factor is 16 dB with a slope of +0.15 dB per GHz to 3 GHz. Insertion loss is 1.5 dB with a slope of +0.1 dB per GHz. Connectors are type-N (f).

HP Model	HP 86205A	HP 86207A
Frequency Range	300 kHz to 6 GHz	300 kHz to 3 GHz
Impedance	50 Ω	75 Ω
Directivity (min)	30 dB, 0.3 MHz to 5 MHz 40 dB, 5 MHz to 2 GHz 30 dB, 2 GHz to 3 GHz 20 dB, 3 GHz to 5 GHz (typical) 6 dB, 5 GHz to 6 GHz (typical)	30 dB, 0.3 MHz to 5 MHz 40 dB, 5 MHz to 1.3 GHz 35 dB, 1.3 GHz to 2 GHz 30 dB, 2 GHz to 3 GHz (typical)
Return Loss (min)	23 dB, 0.3 MHz to 2 GHz 20 dB, 2 GHz to 3 GHz 18 dB, 3 GHz to 5 GHz (typical) 16 dB, 5 GHz to 6 GHz (typical)	20 dB, 0.3 MHz to 1.3 GHz 18 dB, 1.3 GHz to 2 GHz 18 dB, 2 GHz to 3 GHz (typical)
Insertion Loss (max)	1.5 dB, +0.1 dB/GHz	1.5 dB, +0.1 dB/GHz
Coupling Factor (nom)	(<3 GHz) 16.0 dB, +0.15 dB/GHz (>3 GHz) 16.5 dB, -0.20 dB/GHz	(<3 GHz) 16.0 dB, +0.15 dB/GHz (>3 GHz) 16.5 dB, -0.20 dB/GHz