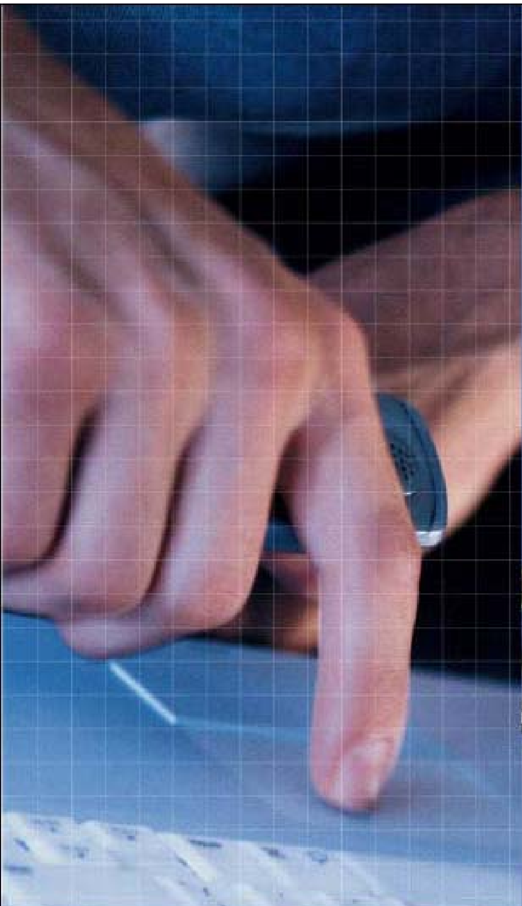


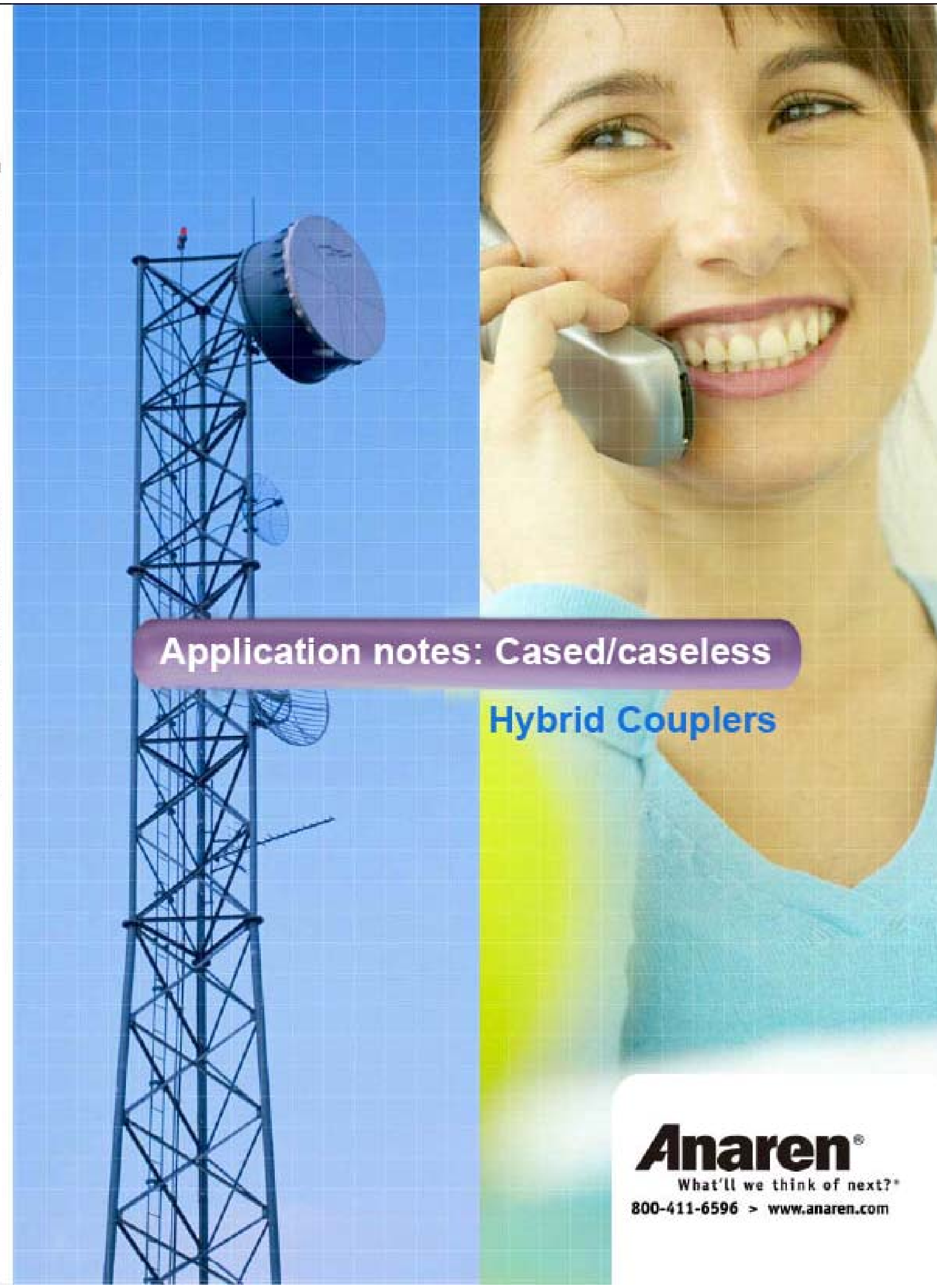
Anaren Microwave,Inc.
6635 Kirkvill Road
East Syracuse,New York 13057
Tel:315-432-8909
Fax:315-432-9121
1-800-411-6596

Anaren Microwave(Europe),Inc.
12 Somerset House,Suite 16 & 17
Hussar Court,Waterlooville
Hampshire,England P07-7SG
Tel:+44-2392-232392
Fax:+44-2392-251369

Anaren Communication (Suzhou) Co.Ltd.
No.4 Zhi He Road West
Suzhou Industry Park
Suzhou,P.R.China 215122
Tel:+86-512-62876400
Fax:+86-512-62749283

Anaren®
What'll we think of next?®
800-411-6596 > www.anaren.com

Anaren® Cased/Caseless Components



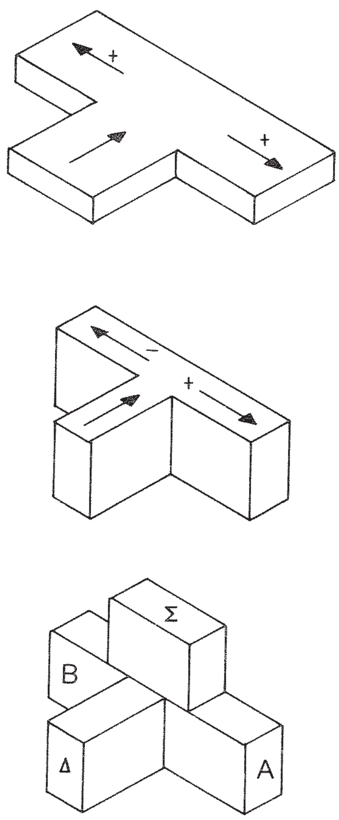
Application notes: Cased/caseless

Hybrid Couplers

Anaren®
What'll we think of next?®
800-411-6596 > www.anaren.com

Coherent power division was first accomplished by means of simple Tee Junctions. At microwave frequencies, wave-guide tees have two possible forms — the H-Plane or the E-Plane tee. These two junctions split power equally, but because of the different field configurations at the junction, the electric fields at the output arms are in-phase for the H-Plane tee and are antiphase for the E-Plane tee. The combination of these two tees to form a hybrid tee allowed the realization of a four-port component which could perform the vector sum (Σ) and difference (Δ) of two coherent microwave signals (A and B). This device is, of course, the magic tee.

Figure 1 - Tee Junctions



Components which perform the same function as the Magic Tee have been realized in many different forms in balanced, coaxial and strip transmission line configurations. Also, lumped component devices which make use of a center-tapped transformer have been built at frequencies up to 1 GHz. (See Figure 2.) The frequency limitation in this device is principally due to the decline of the scalar permeability and the increase in loss of ferrite materials at microwave frequencies.

The distributed versions bear little or no physical resemblance to the waveguide hybrid, but are still sometimes referred to as Hybrids. The Rat Race is an example of a TEM version of the waveguide Magic Tee.

Figure 2 - Distributed Version Of Magic Tee

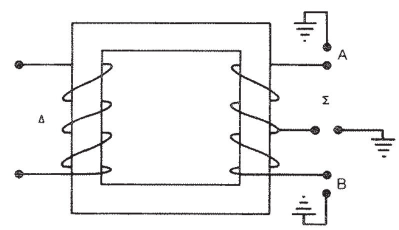
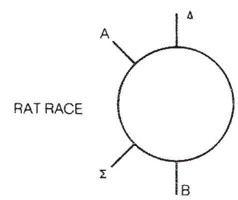
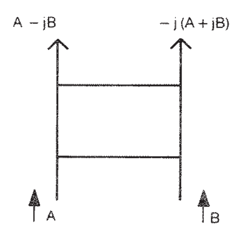


Figure 3 - TEM Version Of Magic Tee



Another device which is also called a hybrid is a Branch-Line Hybrid. This device, however, differs from the Magic Tee and the Rat Race in that the output signals are ±90° relative to each other instead of 0° and 180°. To differentiate between these two types of devices, one is called a 180° Hybrid, and the other a 90° Hybrid.

Figure 4 - Branch Line Hybrid



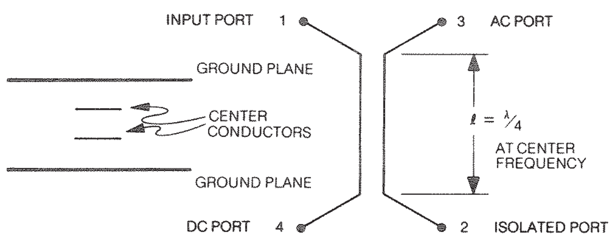
There are many techniques for realizing both quadrature and 180° hybrids in stripline, however, the most versatile versions from a point of view of both performance and bandwidth make use of the backward wave 3 dB coupler. The simplest version of this device is the single section coupler which allows octave bandwidth coverage. The device can easily be designed to cover decade bandwidths and this will be discussed later.

Quadrature (90°) Hybrid

A cross-section and top-view of a backward wave coupler is shown in Figure 5. This consists of a pair of printed lines in close proximity sandwiched between two common ground planes. Analyses of this device may be found elsewhere, meanwhile we will employ an extremely simplified description of operation.

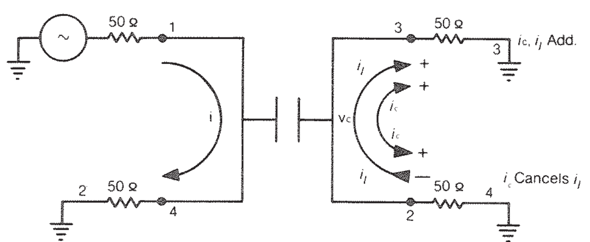
If the length ℓ of the coupled section is very small compared to a wavelength, we can ignore propagation effects and assume that the device is simply a pair of loops whose extremities are terminated in 50 ohm to ground. Because of proximity, the loops are coupled both inductively and capacitively.

Figure 5 - Cross-Section And Top View of Backward Wave Coupler.



Referring to Figure 6, a generator at port 1 will drive a current to ground through port 4. In addition, an inductively coupled current (Lenz's Law) will circulate the coupled loop in the opposite direction as shown. This inductively coupled current will create a potential difference across the 50 ohm terminations at ports 2 and 3 with opposite polarities as shown.

Figure 6 - Illustrating the Coupling Mechanism.

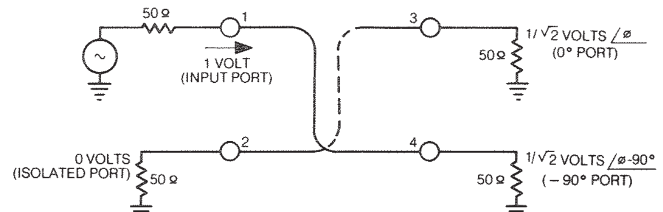


Meanwhile, a capacitive voltage is picked up on the coupled loop owing to the capacitive coupling at the coupled section. This voltage drives a current through the terminations at ports 2 and 3 and creates potential differences across these terminations which have the same polarity.

If we design the device so that the capacitively induced current is equal in magnitude to the inductively induced current, then the voltages across port 2 will cancel each other, while the voltages at port 3 are additive.

This device is a reciprocal 4-port network and can be represented graphically as shown in Figure 7. Note that, for convenience in circuit design, the coupled lines are made to crossover at one extremity. Figure 7

Figure 7 - Signal Relationships in a Properly Terminated 3 dB, 90° Hybrid



An input signal applied to any port (port 1, for example) will divide equally to the two opposite ports (3 and 4) with port 2 remaining isolated. The voltage at port 4 lags the voltage at port 3 by 90°. This phase quadrature relationship is independent of frequency and is the unique property which makes the 90° coupler so versatile.

The power split, however, is frequency sensitive. The frequency characteristics of a backward wave coupler are most easily described by means of a coupling angle θ. This angle is a function of the propogation constant, the width and proximity of the coupled lines and the electrical length of the coupled section. The coupling angle θ varies *almost* sinusoidally with frequency as:

$$\theta \approx \theta_{max} \sin 2\pi\ell/\lambda^{(1)}$$

The maximum coupling angle thus occurs when the coupler length is an odd multiple of quarter wavelengths. θ max depends only on the cross-sectional geometry.

If a signal of strength one volt is applied to one port of the coupler, then the signals appearing at the dc and the coupled (ac) ports are respectively, (ignoring a slight dispersion):

$$V_{dc} = \cos\theta\, e^{-j\beta\ell(2)}$$

and

$$V_{coupled} = j \sin\theta\, e^{-j\beta\ell}$$

If the coupler geometry is arranged such that θ max = 45°, then at the frequency where the coupler length is a quarter wavelength, the output voltages are:

$$V_{dc} = 1/\sqrt{2} \text{ volts } \angle\, \phi - 90°$$

and

$$V_{coupled} = 1/\sqrt{2} \text{ volts } \angle\, \phi$$

This is, of course, a 3 dB coupler.

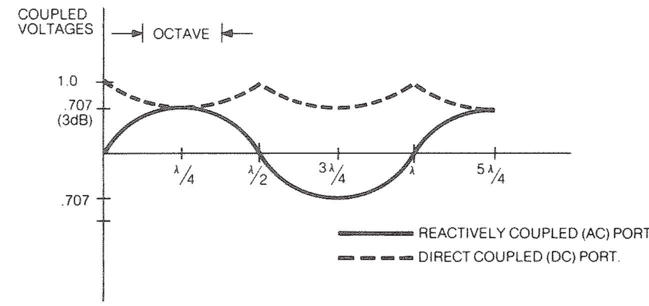
(1) This is an approximate expression. The exact expression is:

$$\theta = \tan^{-1}\left[\tfrac{1}{2}\left(Z'_{oe} - \frac{1}{Z'_{oe}}\right)\sin\beta\ell\right]$$

This introduces a term Z'_{oe} called "normalized even-mode impedance". The use of even and odd mode excitation to facilitate the analysis of a four-port coupler is discussed in an internal Anaren Technical Note "Coupled Lines — Hybrids". Copies of this note can be

As noted earlier, the power split is frequency sensitive. As frequency increases and the length ℓ becomes an appreciable fraction of a wavelength, the coupled voltage varies approximately sinusoidally with frequency as shown in Figure 8. The coupled voltage reaches a maximum when the length ℓ is a multiple of odd quarter wavelengths, and is zero at multiples of half wavelengths. The dc coupled voltage varies approximately cosinusoidally.

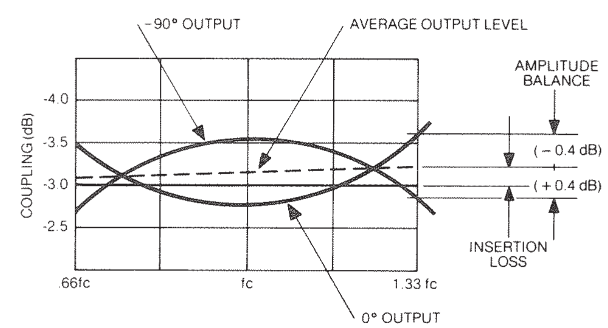
Figure 8 - Amplitude Variation of Coupled Voltages with Frequency



Note in Figure 8 the coupler power split is exactly 3 dB only at band center. When an octave bandwidth must be covered with minimum deviation from a 3 dB coupling value, the coupler geometry is adjusted to make θ = 45 ± 2 degrees. This gives –3 dB ± 0.3 dB of coupling to the output ports. This is a theoretical value and actual practice may result in a maximum of –3 dB ± 0.5 dB due to manufacturing and material yields and tolerances.

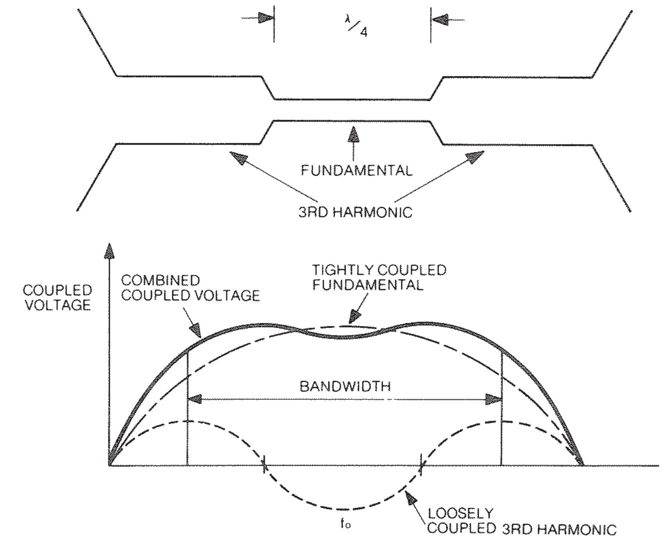
Typical output characteristics of an octave band, 3 dB, 90° hybrid are shown in Figure 9.

Figure 9 - Typical Output Characteristics Octave Band, 3 dB, 90° Hybrid.



To achieve bandwidths greater than octave, we add 3rd, 5th, 7th, etc., harmonics in the form of extensions shown in Figure 10 and with a form of Fourier synthesis we can achieve quadrature hybrids with decade bandwidths where the power split is within ± 0.5 dB and the differential phase-shift between the output voltages is 90°. This technique can also be used to reduce the amplitude imbalance of an octave bandwidth hybrid. Adding more sections, however, adds directly to the insertion loss; for some applications, e.g. balanced transistor amplifiers, benefits gained by the reduction of amplitude imbalance may be negated by this increased insertion loss.

Figure 10 - Illustrating Bandwidth Increase by Adding Loosely Coupled Harmonic Sections.



Common couplers have coupling values of 3 dB, 6 dB, 10 dB and 20 dB. The last three devices are normally called *directional* couplers. The first device is usually called a 3 dB quadrature coupler, or simply 3 dB coupler.

Performance characteristics of 3 dB, 90° hybrids (3 dB couplers) deserve some discussion.

Frequency Coverage

Most designs make use of the single-section coupler which allows octave band coverage. Multi-octave designs are usually 3 or 5 section devices which are larger and generally have poorer isolation and VSWR specifications. Anaren provides hybrids to cover the frequency ranges from 30 MHz to 18 GHz in octave and multi-octave bands.

Isolation

Coupler isolation is defined as the difference in dB between the signal levels at the input port and the isolated port when the two output ports (0° and -90°) are terminated in 50 ohm loads. Since the coupler is a reciprocal device, isolation can also be defined as the signal level difference in dB between the 0° and -90° ports (using one as an input) when the other two ports are terminated in 50 ohm loads.

Theoretically, the backward wave hybrid has perfect isolation independent of frequency. In reality, isolation is limited primarily by turn-to-turn coupling between coupled lines in the meander-line technique. (The meander-line technique does not reduce the physical length of the coupled line but it significantly improves the form factor: 35 inches of coupled line can be meandered in a 2.1 by 2.0 inch package!) As the meander becomes tighter the turn-to-turn coupling causes forward-wave coupling. This not only limits the maximum isolation but also makes the isolation frequency dependent.

When meandering is not a limiting factor on isolation

USA/Canada: (315) 432-8909
Toll Free: (800) 411-6596
Europe: +44 2392-232392
Asia: +86-512-62876400

the VSWR at the output connectors may become so. If the combined VSWR of the stripline/connector transitions and their terminations is not perfect, some energy will be reflected and focused to the isolated port (a VSWR of 1.22 at the output ports would result in an isolation *measurement* of only 20 dB even if the coupler were a truly "perfect" device). The tendency for measured isolation to degrade at the high frequency end of an octave-band hybrid is usually due to the combined effects of increased forward-wave coupling and the poorer VSWR at the output.

VSWR

The input and output impedance match of the coupler is a function of the coupled section and the input/output lines. An additional factor is the quality of the stripline/connector transition.

The effect of VSWR on isolation has previously been discussed. VSWR, like isolation, is also theoretically independent of frequency and dependent upon minimizing the effects of forward-wave coupling. Some internal impedance compensation is possible where the coupled and uncoupled lines interface but tends to be effective over less then octave bandwidths.

Tight manufacturing controls and computer-aided designs assure typical VSWR specifications of 1.10 for tests made with proper test instrumentation.

Amplitude Balance

Amplitude Balance is defined as the difference (in dB) of the signals at the 0° port output and the -90° port output, when compared to the average output level.

Another term sometimes used for Amplitude Balance is "Coupling Frequency Sensitivity". This terminology emphasizes the frequency dependent character of the coupled power from both the 0° and -90° output ports. As noted earlier the amplitude of the coupled voltage varies almost sinusoidally with frequency, reaching a maximum when the electrical length of the coupled section is an odd number of quarter wavelengths.

Because the amplitude of the coupled voltage "rolls-off" each side of band center it is sometimes possible to use a standard 3 dB hybrid to quickly and/or economically obtain a specific coupling value at some lower, or higher, frequency of interest.

Phase Balance

The output ports of a backward wave coupler theoretically remain in phase quadrature independent of frequency. The same factors that affect isolation (forward-wave coupling and poor VSWR at the connector interface) also can degrade phase balance and make it frequency sensitive. The phase balance is not as sensitive to the degrading factors however and a typical phase balance specification of ± 1.0° approaches the limits of resolution, accuracy and repeatability for most phase measurement schemes.

Insertion Loss

Coupler insertion loss is defined as the net unrecoverable power (in dB) based on one-way transmission through the coupler.

The insertion loss is dependent upon several factors and can be considered to be the sum of several losses. The first of these is the I^2R loss due to the copper conductor resistance. The lost energy is dissipated as heat.

The second loss is dependent on the degree of match obtained at the coupler inputs and outputs. Any departure from the optimum match will result in a loss of signal delivered to the coupler and a subsequent loss of available signal to the output loads. A VSWR of 1.20 at the input and output ports will result in a mismatch loss of approximately .09 dB.

The third loss is in the form of directivity losses. A perfect coupler would focus all the input power to the two output ports and none would show up at the isolated port. If the measured isolation of the coupler is 20 dB the directivity is equal to 17 dB (Directivity = isolation minus coupling loss). 17 dB directivity results in .085 dB of the input power not being directed to the output ports.

Power Handling

Power handling capability of a 90° hybrid coupler decreases with increasing signal frequency. For example, a standard coupler handling 220 watts at 440 MHz could be expected to handle 160 watts at 880 MHz.

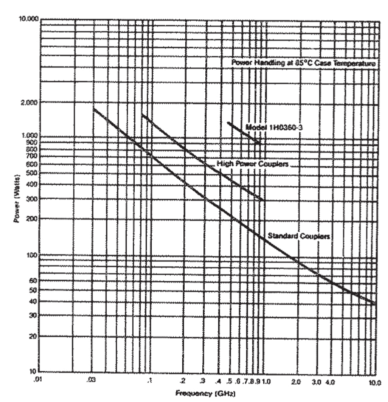


Figure 11 - Power Handling vs. Signal Frequency for Anaren 90° Caseless Couplers

Output Configurations

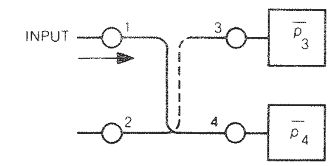
To provide the maximum flexibility for installing the hybrids in a system Anaren offers miniature hybrids with two choices of output port configurations: Standard and H-Style.

Applications of the 3 dB, 90° Hybrid

Because of the 90° relative phase difference in the output signals, the 3 dB, 90° hybrid is used extensively in many microwave applications.

If the output ports (3, 4) of the 3 dB hybrid in Figure 7 are short-circuited to ground, then power into port 1 is reflected to port 2. In fact, if ports 3 and 4 are terminated with any *identical* components, then any reflections from these components will appear at port 2. This simple behavior allows us to obtain an apparent input match to badly mismatched components.

Figure 12 – 3 dB, 90° Hybrid Terminated with Reflection Coefficients, $\bar{p}$



Let us examine this behaviour in more detail using Figure 12. Let $\bar{p}$ be a complex voltage reflection coefficient:

$$\bar{p} = p\,e^{j\theta}$$

where

p = magnitude of the complex voltage reflection coefficient
θ = phase angle of the complex voltage reflection coefficient

With ports 3 and 4 terminated with voltage reflection coefficients $\bar{p}_3$ and $\bar{p}_4$ respectively, and a signal applied to port 1, the reflection coefficient at Port 1 is:

$$\tfrac{1}{2}(\bar{p}_3 - \bar{p}_4)$$

and at Port 2:

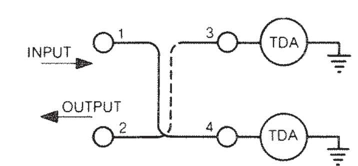
$$\tfrac{1}{2}(\bar{p}_3 + \bar{p}_4)$$

If the output reflection coefficients are equal ($\bar{p}_3 = \bar{p}_4$) then the input port is perfectly matched. This is true even for such drastic output conditions as open or short circuits.

This characteristic of directing reflected energy away from the input port to the normally isolated port applies not just for open or short circuit output ports but for any equal impedance terminations. This simple behavior provides a very low input VSWR to badly mismatched but similar components. These features are used in balanced transistor amplifiers, tunnel diode transmission line amplifiers, phase shifters, and balanced detectors and balanced mixers, to name a few.

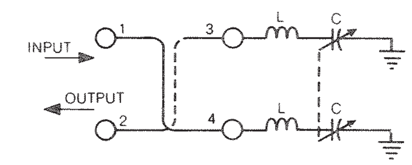
Two identical tunnel diode amplifiers (TDA) connected to the coupler, as shown in Fig. 13, form a transmission line amplifier.

Figure 13 – TDA Transmission Line Amplifier



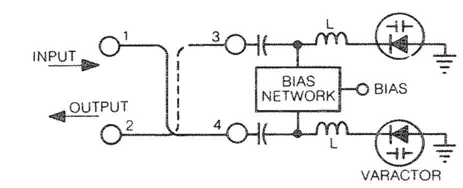
A manually controlled phase-shifter can be obtained by using variable L-C networks as shown in Fig. 14. The insertion phase (from input to output) varies as C is varied but the input match is maintained.

Figure 14 – Manual Phase Shifter



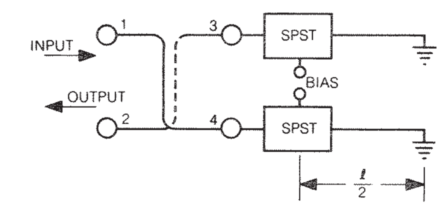
An electronically controlled phase shifter is obtained by replacing the manually variable capacitors of Fig. 14 with the bias-variable varactor diodes of Fig. 15.

Figure 15 – Electronic Phase Shifter



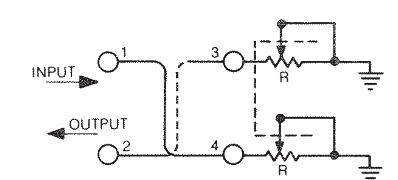
A single-bit, electronic time delay or phase shift is obtained by means of a coupler and two PIN SPST switches, as shown in Fig. 16.

Figure 16 – Single-Bit Phase Shifter



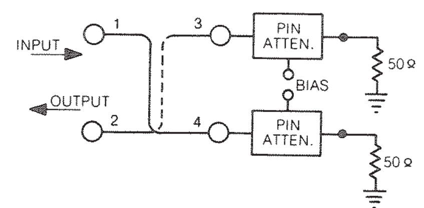
A manually controlled attenuator with good input match is shown in Figure 17. A pair of variable, tracking resistors controls the amount of input signal absorbed or reflected. This varies the attenuation level from minimum to maximum.

Figure 17 – Manual Attenuator



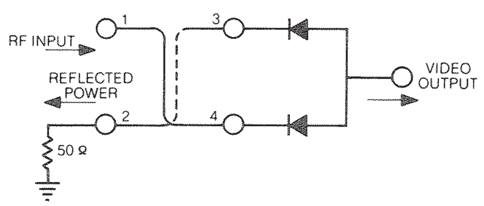
An electronically controlled, matched attenuator is obtained by replacing the variable resistors with PIN diodes and associated bias networks. Varying the PIN diode bias current controls the diode RF inpedance, thereby controlling the attenuation level. Fig. 18 illustrates the technique.

Figure 18 – Electronic Attenuator



A matched detector is obtained by using a pair of similar detector diodes as shown in Fig. 19.

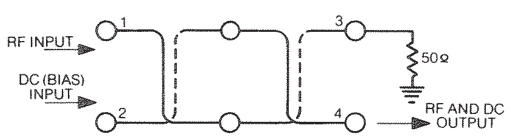
Figure 19 – Balanced Detector



If two 3 dB, 90° hybrids are connected in tandem, the resulting four-port network displays some additional interesting properties. This occurs because two couplers connected back-to-back behave like a single coupler with a coupling angle equal to the sum of the two individual coupling angles.

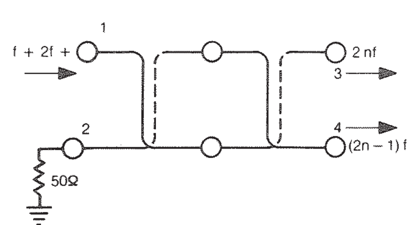
If each of the two couplers have maximum coupling angles of 45° (3 dB couplers) the combined coupling angle is 90° (a 0 dB coupler). This allows a simple biasing input to active RF components because it provides a crossover at the RF frequency but a straight-through path at dc, as shown in Fig. 20.

Figure 20 – Separation of RF and Bias Inputs



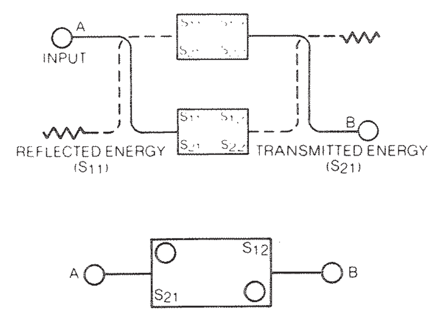
When octave bandwidth 3 dB couplers are used in the tandem network of Fig. 21, the circuit can be used to separate even and odd harmonics, to losslessly combine harmonic signals, or as a signal diplexer. See page 90 for a detailed treatment of the diplexer application.

Figure 21 – Signal Diplexer



When two identical two-port devices are placed between two 3 dB, 90° hybrids, a new matched two-port network is obtained which retains the cross-scattering coefficients.

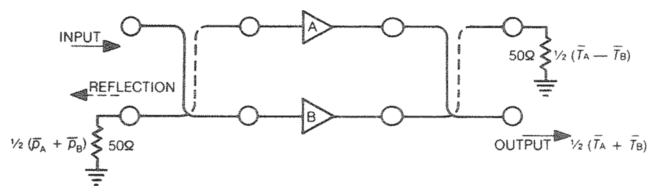
Figure 22 – Use of 3 dB, 90° Hybrids to Obtain a Matched Two-Port Devices by Paralleling Identical Devices.



The input signal divides equally in the first hybrid as usual, but the second hybrid now acts as a summing tee network and all the original signal (expect for circuit losses) appears at only one output port of the second hybrid. The other output port is isolated.

When any two circuit components (transistors, for example) have complex voltage transmission coefficients T_A and T_B (and reflection coefficients $\bar{\rho}_A$, $\bar{\rho}_B$) are placed between two hybrids, the voltage transmission of the complete network is: $\frac{1}{2}(T_A + T_B)$

Figure 23 – Balanced Amplifier



(The voltage $\frac{1}{2}(T_A - T_B)$ is absorbed in the termination of the isolated output port).

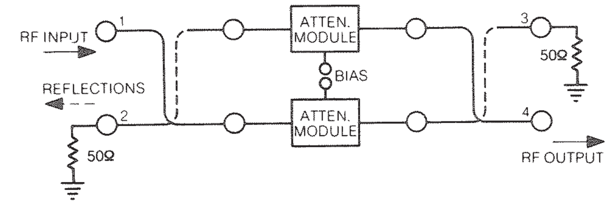
When the transmission coefficients are identical ($T_A = T_B$) then none of the transmitted signal is lost to the isolated port and all appears at the output. When the input reflection coefficients ($\bar{\rho}_A$, $\bar{\rho}_B$) are identical the input hybrid sums all the reflected voltage, $\frac{1}{2}(\bar{\rho}_A + \bar{\rho}_B)$, to the termination at the isolated input port.

The new network of Fig. 23 is a balanced amplifier having low input VSWR and output power twice that a single transistor.

Replacing the transistors of Fig. 23 with PIN diode attenuator modules, where the reflection and transmission coefficients are varied by the use of dc bias, results in a series of useful electronically controlled devices. (A PIN diode acts as a variable RF resistance, the RF resistance being controlled by a bias current).

Analog control of the bias inputs of Fig. 24 results in a matched, variable attenuator also useful as an amplitude modulator. Digital bias results in a matched on-off switch or pulse modulator.

Figure 24 – Matched Analog/Digital Attenuator/Switch



Using the reflected energy results in a single-pole, double-throw (SPDT) switch:

Figure 25 – Matched SPDT Switch

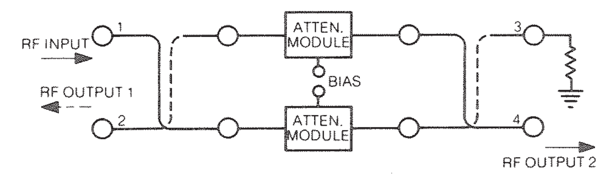


Figure 26 – Matched DPDT Switch

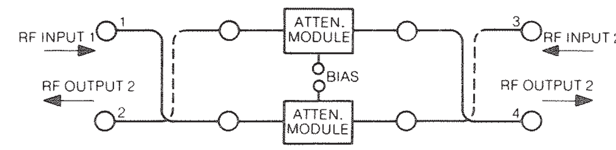
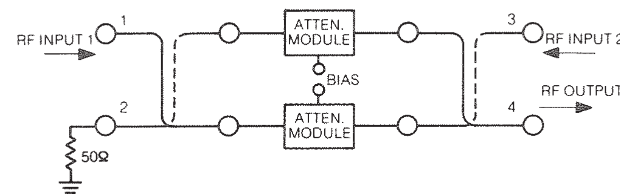


Figure 27 – Matched DPST Switch



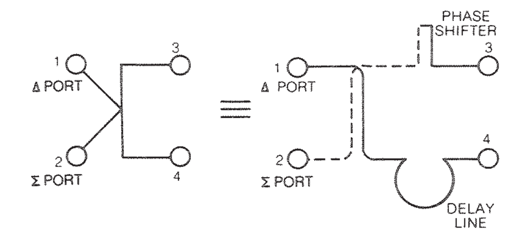
Anaren 3 dB, 90° hybrids are also used as the RF and IF building blocks for more complex devices; balanced mixers, balanced (bi-phase) modulators, double-sideband and single-sideband modulators, image-rejection mixers, quadraphase and vector modulators, frequency and phase discriminators and a variety of adaptive networks. More details on these devices can be found by consulting the overall contents in the front of the catalog.

3 dB, 180° Hybrids

Many signal processing applications also make use of the 3 dB, 180° hybrid as well as the 90° hybrid. The waveguide "magic tee" and the stripline/microstrip "rat-race" configuration are narrow-band examples of the 180° hybrid. This device is similar to the 90° hybrid in most respects except that the output voltages are either in-phase or anti-phase, depending on which input port is used.

To convert a 90° hybrid to a 180° hybrid a fixed 90° phase shift is required at one of the outputs as shown in Figure 28. This is achieved, over octave bandwidths, by using a Schiffman[1] phase-shifter which is simply a dispersive transmission line inserted in one output of a quadrature hybrid.

Figure 28 – 180° dB Hybrid

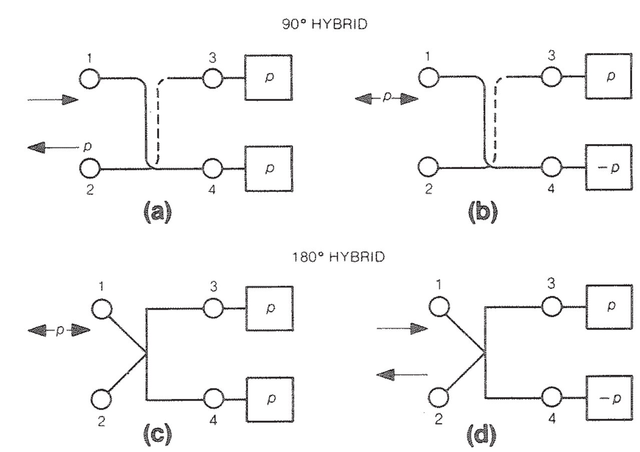


The 180° hybrid shown in Figure 28 is non-reciprocal. 180° phase difference between outputs 3 and 4 occurs only when the differnce (Δ) port is excited. The outputs are in-phase when the sum (Σ) port is driven.

The simple addition of a 90° phase-shift results in a considerable difference in characteristics of the 180° hybrid as compared to the 90° hybrid. These are best illustrated when the output ports are terminated with devices having like reflection coefficients.

In Figure 29 we see that the reflected energy comes out at the isolated port for a 90° coupler (Figure 29a) and the input port of a 180° hybrid (29c).

Figure 29 – Reflective Properties of 90° and 180° Hybrid with Even and Odd Reflection Coefficients



If the reflection coefficient of *one* of the mismatches were changed by 180°, the situation would be reversed. That is, the reflected energy would come out the input port of a 90° coupler (29b) and out the isolated port of a 180° coupler (29d). These properties are fundamental to devices such as absorptive PIN modulators, balanced modulators, single sideband modulaators and image rejection mixers.

[1]Schiffman, D.M., "A New Class of Broadband Microwave 90 Degree Phase Shifters," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, Vol. MTT-6, pp. 232-237, April, 1958.

Applications of the 3 dB, 180° Hybrid

The 3 dB, 180° hybrid is used in many of the same applications as the 90° hybrid. If a power split is required the 180° hybrid has the option of providing in-phase or anti-phase outputs. This property finds use in polarization schemes for antenna feeds and beam-forming networks. In many cases it is the reflective properties that make the 180° hybrid useful. A balanced mixer can be constructed by utilizing two mixer diodes and either a 90° or 180° hybrid. If a 90° hybrid is used, both the LO and RF would see a relatively good match, but the LO to RF isolation would be poor. In the case of a 180° hybrid, the VSWR of the LO and RF is poor, but the LO to RF isolation is greatly improved over that obtained by means of the 90° coupler balanced mixer (like reflection coefficients in Figure 29c).

Figure 30 - 180° Balanced Mixer with Good LO/RF Isolation, Poor VSWR

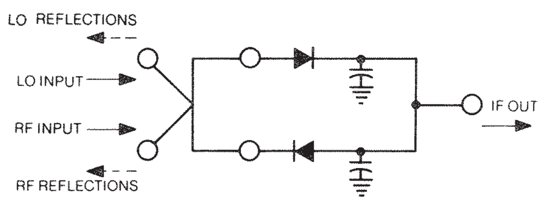
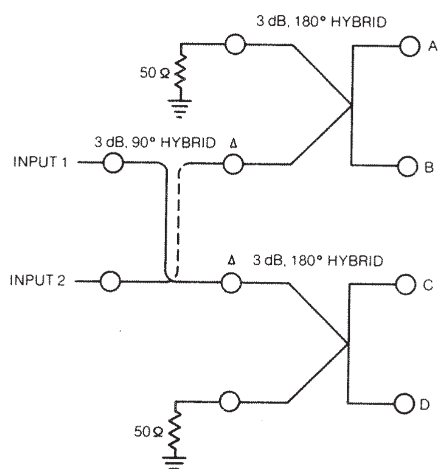


Figure 31 illustrates the use of Anaren's hybrid couplers to produce a circular polarization antenna feed network. the network will generate both right hand (RHC) and left hand (LHC) circular polarization depending on which input to the 90° hybrid is chosen as the feed input.

The relative phasing of the output ports versus the excited input port is shown below.

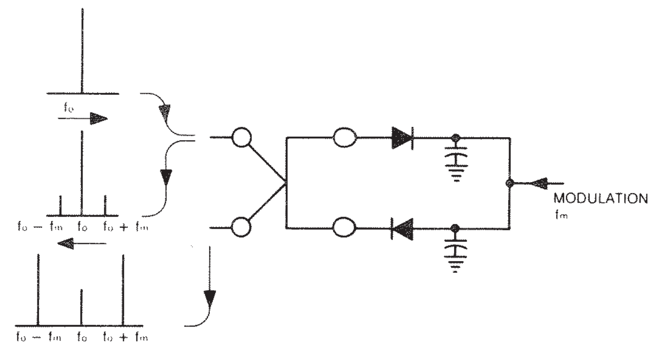
Output Port	Using Input 1	Using Input 2
B	0°	90°
C	90°	0°
A	180°	270°
D	270°	180°

Figure 31 - Circular Polarization Network, LHC, RHC, Using Anaren Hybrids



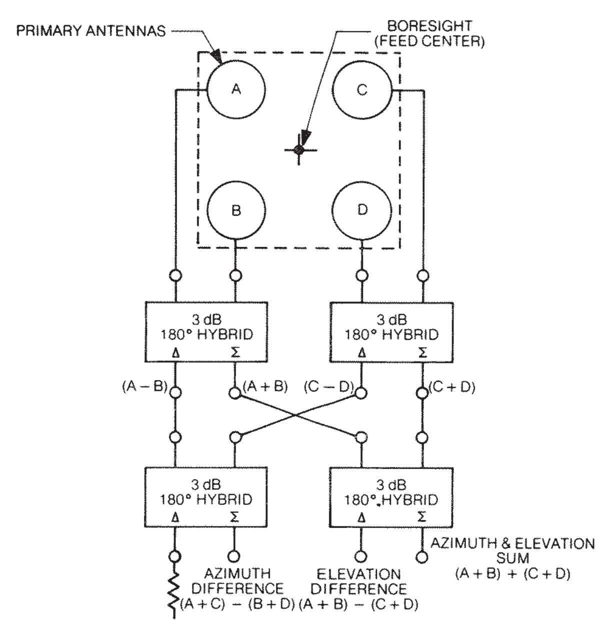
A balanced modulator can be constructed by placing two mixer diodes with reverse polarity behind a 180° hybrid, and combining the IF in a tee as shown in Figure 32. (The same circuit as Fig. 30.) The incident RF would see like reflection coefficients at the diodes and reflect back to the input port. The biasing signal in the IF port produces opposite polarity reflection coefficients at the sum and difference frequencies and the modulated signals appear at the remaining port. The amount of carrier suppression depends on the quality of the 180° coupler and the similarity between the diodes. Octave bandwidth carrier suppression of 10 dB and narrow bandwidth suppression of 25 dB are typical.

Figure 32 - 180° Balanced Modulator with Good Carrier Suppression, Poor VSWR



Monopulse tracking systems obtain tracking information by fixed (rather than scanning) beams. A typical two-dimensional system utilizes four primary antennas grouped around the feed point as shown in Figure 33. The feed network consists of four, 3 dB, 180° hybrids.

Figure 33 - Monopulse Tracking System



The received energy is focused to either the sum or difference port of a 180° hybrid, depending on the phase relationship of the received RF signal. From the input ports (A, B and C, D) of the hybrids, in-phase RF energy combines at the Sum (Σ) ports and out-of-phase energy at the Delta (Δ) ports. These sum and difference outputs are further combined to provide elevation (and azimuth) differential patterns. These patterns are zero (nulled) along boresight, and maximum on either side of boresight. The tracking error signal is produced by comparing the sum signal to each of the differential patterns. When the received signal is on boresight, the azimuth and elevation difference information is at a null and the sum information is at a peak output level. As the received signal deviates from boresight, the sum channel output level decreases as either (or both) difference channel outputs increase. Thus the relative level of the outputs determines the target location.

Directional Couplers

The directional coupler provides a simple, convenient means for monitoring or sampling RF energy. Because it can sample transmission line power by a known amount, accurate measurements can be made without system interruption. The directional coupler can also monitor system operating frequency, provide a signal sample for automatic leveling and frequency control loops and provide indications of reflected power on the transmission line.

Coupling Values

Anaren provides standard coupling values of 6, 10, 20 and 30 dB. The choice of coupling value normally depends on the power levels involved. For example, if the coupler is used to monitor mainline power the coupling value would be selected to provide sufficient power to the monitoring device for proper operation. It must also be remembered that any coupler reduces power flowing in the main line by the amount coupled off: a 6 dB coupling value reduces the main line power output by 1.25 dB, while a 20 dB coupler reduces it by only .044 dB.

Directivity

Directivity indicates the degree to which the coupled port is isolated from the main line load. Open or short circuiting the output port of a directional coupler having 20 dB directivity would affect the coupled output power by only about 1%. High directivity is especially important if the coupler is being used to measure VSWR of a test device on the output port.

Insertion Loss

Low insertion loss is desirable because it means there is more power available to the rest of the system. Insertion loss increases with increasing frequency and coupler bandwidth. The insertion loss specification for Anaren directional couplers *does not* include the losses due to coupling.

VSWR

Low mainline VSWR is perhaps more important than coupled port VSWR simply because the main line ports produce the possibility of mismatch errors into the system. Any coupled port mismatch is isolated from the main line input by the amount of coupling and from the main line output by the coupling and directivity.

Bandwidth

Selecting a coupler with broad bandwidth involves some tradeoffs. Broad frequency coverage is usually accompanied by reduced coupling accuracy, reduced directivity, increased VSWR, increased frequency sensitivity, increased insertion loss and larger size. When a choice is available, it is better to specify the narrowest bandwidth possible.

Power Handling

Power ratings for Anaren's directional couplers are specified for CW power, in both the forward and reverse directions. The ratings for the "in-line" style of couplers takes into account the possibilities of an open or short circuit output load which would reflect the transmitted load power back to the coupler's internal termination. Since some of these terminations will dissipate only 300 mW at 95°C the 6 dB couplers are rated at 1 Watt max reverse power. The H-style couplers have isolated ports that are available for external terminations. Greater reverse power can therefore be handled dependent on the power rating of the external termination actually used.

Input/Output Configurations

Anaren offers two input/output port configurations which are referred to as In-Line and H-Style, Representatives of each style are shown in Figure 34 and 35. Two styles provide optimum flexibility for solving system packaging problems.

Figure 34 - In-Line Directional Coupler

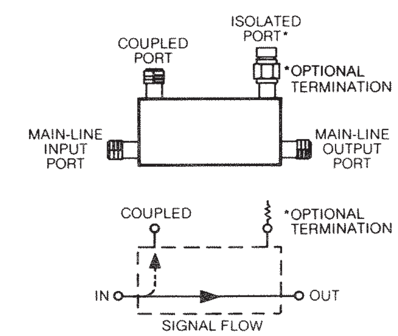


Figure 35 - H-Style Directional Coupler