

Power Dividers and Hybrids

Introduction

Traditionally, both coupled-line 3 dB couplers and in-phase Wilkinson dividers have been used for power dividing and combining. For a given application, however, the differences between the two make one type more desirable than the other.

90° Hybrids

A 90° Hybrid (Hybrid Junction) is a network having the electrical characteristics of a 3 dB directional coupler whose branch line is not terminated. The four terminal network can be considered to have two pairs of terminals called conjugate pairs. In most packages, each conjugate pair is located on either side of the device (Figure 1). The two terminals that make up the conjugate pair are isolated from each other. Therefore, power flowing into one terminal of the pair does not appear at its conjugate, but is equally divided between the terminals of the opposite conjugate pair. When used as a power divider, any one of the four terminals can be used as the input. With the conjugate port of the input terminated in 50 ohms, the two outputs at the opposite conjugate pair will be of equal amplitude and in quadrature (90° apart in phase).

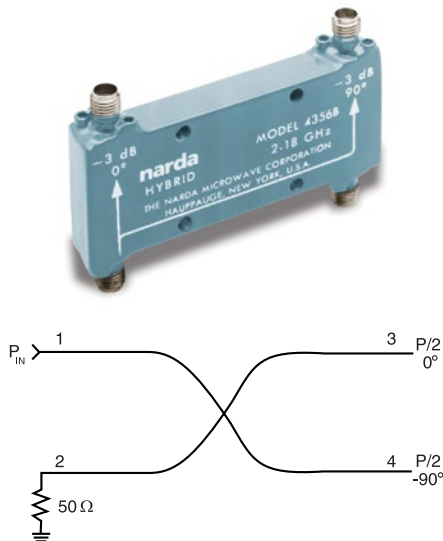


Figure 1 Multi-Octave Hybrid
Ports 1 & 2 Comprise a Conjugate Pair
Ports 3 & 4 Comprise a Conjugate Pair

The primary advantage of the hybrid junction is its power handling capability. Since the isolated port (conjugate of the input port) is terminated externally, the only limitations to power handling are heat generated by the internal dissipation losses and the power handling capability of the external termination. As stripline losses are typically low, hybrid junctions can be designed to handle up to 500 watts average power in special versions. Another advantage of the hybrid junction is that it maintains its quadrature relationship over the full operating frequency range of the device. This characteristic is highly desirable in Polar Frequency Discrimination and Circularly Polarized antenna circuits.

180° Hybrids

A signal applied to the sum port of the 180° hybrid provides output signals of equal amplitude and phase at the output ports. A signal applied to the delta port provides output signals of equal amplitude but 180° out of phase with each other (Figure 2). Narda Broadband 180° Hybrids are ideal for use as power dividers, combiners, balanced mixers, image rejection mixers, antenna feed networks, matrix amplifiers and switching networks.

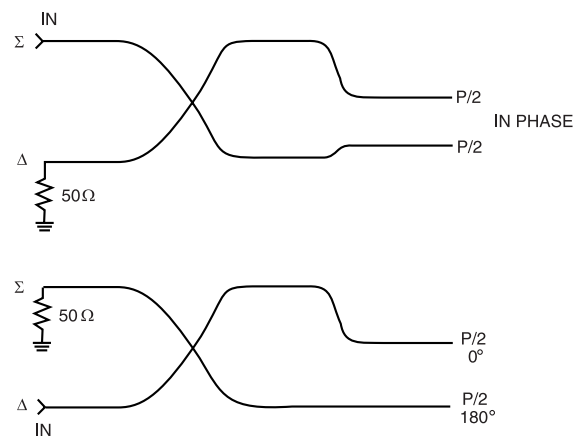


Figure 2 Signal Flow Diagram 180° Hybrid



Power Dividers and Hybrids

In-Phase Power Divider

The in-phase Wilkinson power divider is a network with one input and N outputs equal in amplitude whose phase relationship is zero degrees. In some applications, such as phased arrays and certain EMC interferometer receiving systems, this characteristic is a necessity.

A distinct advantage of the in-phase power divider is its superior amplitude balance when compared to the amplitude balance of a hybrid junction. Examples which take advantage of this superior performance are illustrated in Figures 3 and 4. Since the output ports track so closely, one port of the divider is fed back to the swept signal generator to provide a very flat amplitude response at the point of measurement.

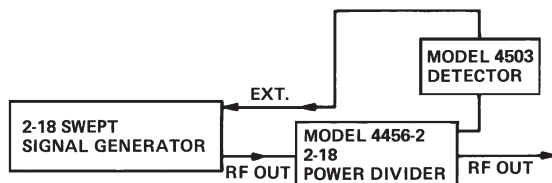


Figure 3 - An example using a power divider in a leveling loop application requiring superior amplitude and phase balance.

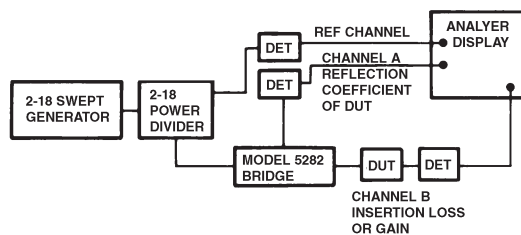


Figure 4 - A ratio measurement system is an example in the use of the excellent tracking characteristics of the divider

As the output ports of the divider are identical, and one of these outputs is used to provide amplitude correction information to the swept generator, the ideal case provides a constant RF output level to the unit under test. When this is the case, measurement of reflection coefficient and insertion loss of a device may be made with a swept signal generator in the unlevelled mode. Any inadvertent variation of the power output control of the swept signal generator would have no effect on the measurement. It should be noted, however, that in both of the cases depicted in Figures 3 and 4, there is a nominal 3dB power loss of the input signal.

Using Hybrids and In-Phase Power Dividers as Power Combiners

Both the in-phase power divider and the hybrid junction can be used as power combiners. If the relationship of the input signals when the device is used as a combiner is the same as the relationship of the output signals present when the device is used as a divider, there is a minimal power loss through the device. For example, a 90° hybrid with equal amplitude signals in quadrature placed on the inputs to one conjugate pair will result in no signal at one of the terminals of the opposite conjugate pair and the sum of the signals at the other terminal. Due to the fact that the inputs, when used as a combiner, were at the same relationship as the outputs would have been if the device was used as a divider (one signal in, two signals out at equal amplitude 90° apart) the power loss is minimal. In other cases, the combination losses will vary with the relationship of the signals, and the combined power level achieved in combination will be degraded.

In a similar manner, the in-phase power divider can be used as a power combiner. In this case, however, as the power handling capability of the in-phase power divider is limited by the power handling capability of the internal resistor(s) of the device, the input power level of each of the combined signals must not exceed $1W/N$ watts (where N is the number of inputs). For example, when using a 4-way power divider as a combiner, the maximum power level into each of the output ports of the divider cannot exceed 0.25 watts or $1W/N=4$. If, however, the input signals are phase and amplitude coherent (same frequency, equal amplitude), the internal resistor of the in-phase power divider does not dissipate energy, and the power level of the inputs can be as high as the full-rated power used as a divider, divided by N. In this example, a 4-way device rated as a divider at 50 watts, could handle 4 signals of 12.5 watts if the signals were *perfectly* frequency- and amplitude-coherent.

In applications for the combination of 2 or more transmit signals into single antenna communications networks, Narda does provide designs that can handle multiple signal inputs at elevated RF power levels. Power level handling, where the sum of the input signal power of each of the input ports closely matches the maximum forward power when used as a divider, is readily

Power Dividers and Hybrids

achievable with the proper resistor selection. Using this design approach, custom broadband high frequency devices, as well as narrow band products geared toward the cellular markets, are available.

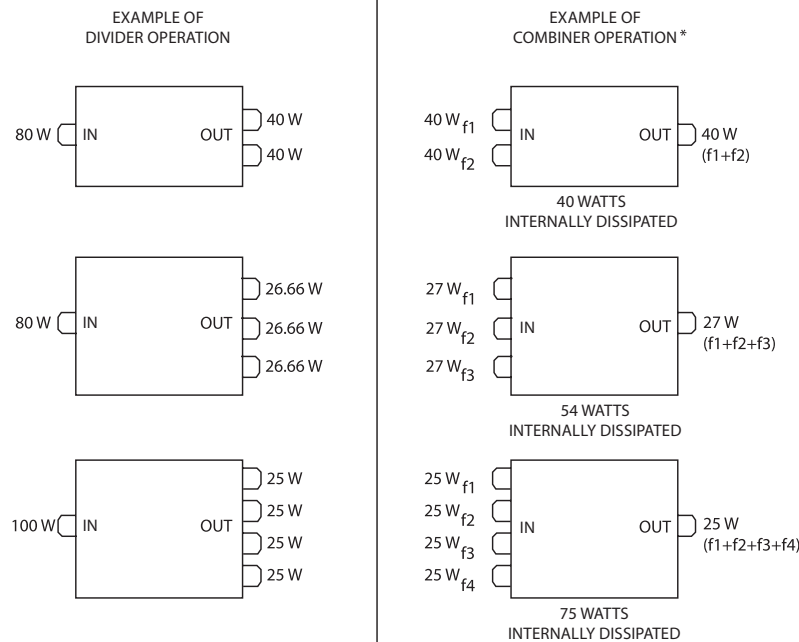
When a signal is applied to the input of a Wilkinson power divider, it results in signals at the output that are equal in amplitude and phase (with respect to each other). Ignoring the effects of insertion loss (that loss above and beyond the theoretical or split loss), the output signals are at an amplitude that is half the amplitude of the input signal. This concept can be expanded for devices with more than two outputs: i.e., the output power is equal to the input power, divided by "N" the number of outputs ($P_{OUT} = P_{IN} / N$). In dB, the relationship would be $Out_{dB} = 10 \log (1 / N)$.

When non-coherent (other than matched in phase and amplitude) signals are introduced into the outputs as a combiner however, the device will dissipate a considerable amount of energy and as such, special consideration must be taken in the management of that dissipated power. For example, with traditional low-power designs, a two-way divider rated for 30 watts

(30 watts in, two 15 watt signals out) would produce catastrophic results if two non-coherent 15 watt signals were applied (P_{IN} / N or $30 \text{ W} / 2 = 15 \text{ W}$). In a two-way device, half of the energy of each signal to be combined would need to be dissipated in the internal resistors. If special provisions were not taken to handle this power, the device would be destroyed. With non-coherent signal inputs, the loss of each signal will be identical to the loss of the device when used as a divider. In the combiner case, that loss is dissipated in the internal resistors.

With the utilization of proprietary thermal-management techniques and special material / assembly methods, Narda provides a series of Wilkinson-style devices that have the capability of handling elevated RF power levels as a non-coherent signal combiner. For example, our 80 watt, 2-way device (Narda Model 2362-2) handles 2 x 40 W signals ($80 \text{ W} / 2 = 40 \text{ W}$), and the 80 watt, 3-way device (Narda Model 2362-3) handles 3 x 27 W signals ($80 \text{ W} / 3 = 26.66 \text{ W}$). The diagram in Figure 5 illustrates the general function for 2, 3, and 4-way devices, in terms of their use as non-coherent signal combiners.

Figure 5



NOTES:

CONSIDERS THEORETICAL LOSSES ONLY.
ADDITIONAL I²R LOSSES ARE NOT INCLUDED IN THIS ANALYSIS.

* CASE TEMPERATURE MUST BE MAINTAINED AT 85° MAX.
COOLING FAN MAY BE REQUIRED.

Power Dividers and Hybrids

Glossary

Since performance characteristics of in-phase power dividers are specified in a number of ways, the following definitions of terms are applicable to all Narda in-phase power dividers that appear in this catalog.

Frequency - The frequency range over which the power divider must meet specifications listed.

Amplitude Balance - The maximum peak-to-peak amplitude difference in dB between the output ports of the power divider over the specified frequency range.

Phase Balance - The maximum peak-to-peak difference in phase, in degrees, between the output ports of the power divider over the specified frequency range.

Isolation - The difference in dB that the signal level measured at one output port is below the signal level into the adjacent output port, with the input port terminated in 50 ohms. Isolation is measured between adjacent ports since this is the most severe condition.

VSWR, Input - The maximum VSWR of the power divider over its specified frequency range, looking into the common port, with all other ports terminated in 50 ohms.

VSWR, Output - The maximum VSWR of the power divider over its specified frequency range, looking into any one of the output ports with all other ports terminated in 50 ohms.

Insertion Loss - The ratio in dB of the net difference between the power input and the sum of the output power expressed as:

$$\text{Insertion Loss} = 10 \log \left[\frac{P_1 + P_2 + \dots + P_n}{P_{\text{input}}} \right]$$

Average Power - The maximum power that may be applied to the common or input port with the output ports terminated in a load with the VSWRs listed.

NOTE: For Applicable Narda Power Dividers and Hybrids, Narda can supply **standard** test data for a nominal fee.

Environmental Performance for Selected Passive Products*

| PARAMETER | SPECIFICATION |
|-----------------------|---|
| Operating Temperature | -54 to +105°C |
| Storage Temperature | -55 to +125°C |
| Humidity | Per MIL-STD-202F, method 103B, condition B (96 hours at 95% R.H.) |
| Shock | Per MIL-STD-202F, method 213B, condition J (30G, 11 ms) |
| Altitude | Per MIL-STD-202F, method 105G, condition B (50,000 feet) |
| Vibration | Per MIL-STD-202F, method 204D, condition B (.06" double amplitude or 15G, which ever is less) |
| Thermal Shock | Per MIL-STD-202F, method 107D, condition A (5 cycles) |

* Applicable to Stripline Directional Couplers, Attenuators, Power Dividers

Note:

This is an exclusive listing. Where otherwise noted in the catalog, the above environmental performance may not apply. Not applicable for those products designed for commercial applications. Many of our catalog off-the-shelf (COTS) products have the ability to withstand considerably more stringent environments. If you have special environmental requirements, please contact the Sales Department at Narda.