0° POWER DIVIDERS/COMBINERS

LUMPED ELEMENT AND STRIPLINE
10 KHZ - 40.0 GHZ

GENERAL DISCUSSION

Merrimac in-phase power dividers/combiners fulfill two complementary roles. As dividers, these devices take a single input signal and split its power equally between two or more outputs. The phase difference between all outputs is extremely small. As a combiner, these devices take two or more inputs and produce the vector sum at the output.

Table 1 shows the coupling losses of reactive hybrid power dividers assuming no power loss.

Quality of Outputs	Coupling (dB)
2	-3
3	-4.78
4	-6
5	-7
6	-7.78
8	-9
16	-12
N	-10logN

Table 1: Ideal Coupling Loss

TYPES OF DIVIDERS/COMBINERS

Merrimac manufactures two basic types of dividers/combiners:

1. Those using **lumped element circuits** are generally used at lower frequency and power levels.
2. Those using **stripline technology** are generally used for higher frequencies and power levels and where low loss is essential.

Merrimac's family of power dividers consists of a variety of hybrid networks grouped according to:

1. Total number of outputs
2. Power handling capacity
3. Frequency
4. Size

Standard units include models with output ports varying in quantity from 2 to 12. Frequencies covered range from 10 kHz through 40 GHz. Customized units with binary power division up 64:1 and prime number (non-binary) dividers such as 5:1, 7:1, 11:1, et al, are available in custom models.

THEORY OF OPERATION

The basic binary power divider comprises a hybrid junction with one of its four ports internally terminated. For power dividers with in-phase outputs, the ''E'' (series) port is internally terminated. For out-of-phase outputs the ''H'' (shunt) port is internally terminated.

Figure 1 schematically illustrates a basic 2-way power divider. Figure 2 illustrates a basic 3-way power divider.

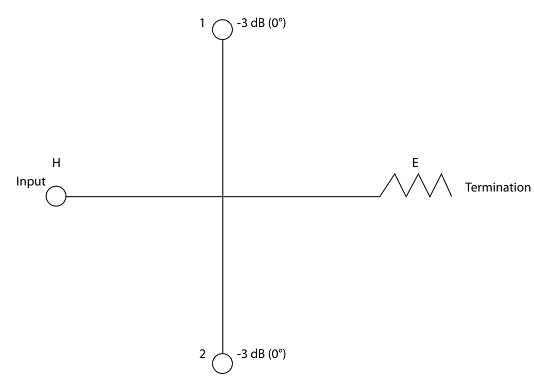

Figure 1: Basic Schematic of Two-Way, In Phase Power Divider

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In typical power-splitting applications, signals applied to the common (input) port are equally divided between output ports 1 and 2 while the relative phase difference between the outputs approaches zero. Additional binary power dividers are connected to each output port if further sub-division is required.

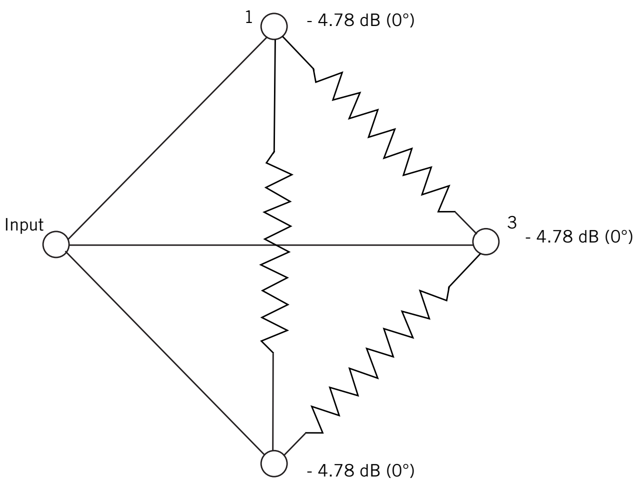


Figure 2: Basic Schematic of Three-Way, In Phase Power Divider

Prime number power dividers require networks designed for the specific quantity of outputs required. In the basic three-way power divider, signals applied to the common port split equally , in phase, at the outputs. In the 3-way divider the coupling is -4.78 dB meaning that the power level at each of the three output ports is 4.78 dB below that of the input power level.

When performing as combiners, hybrids provide the vector sum of the various inputs. Fully coherent signals (i.e., signals of the same amplitude and phase) applied to the combiner inputs will produce the vector sum at the single combiner output port. If combiner inputs differ if any respect (e.g., amplitude, phase or both) the resulting output will be a complex derivative of the sum of the inputs less the complex insertion loss(es).

DEFINITIONS

1. **Coupling and Insertion Loss:** The total transmission loss within a power divider is the sum of the coupling loss and the insertion loss.

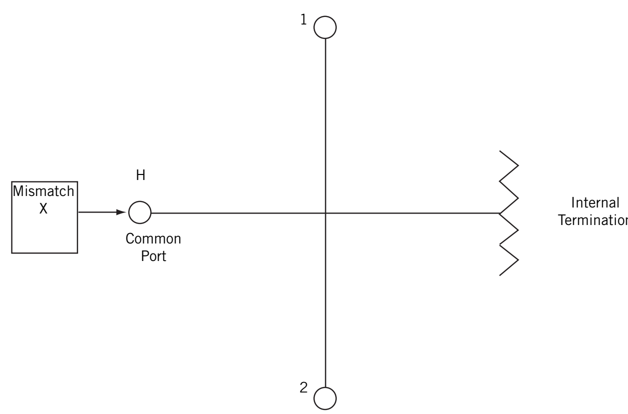
   These are defined as follows:

   A. Coupling Loss - Expressed in dB, coupling loss is the power level that would be expected at each of n-ports when the input power level is equally split n-ways exclusive of other losses. See Table 1 for coupling loss versus quantity of output ports.

   B. Insertion Loss - The net unrecoverable power dissipated within the circuit.

2. **Isolation:** Expressed in dB, isolation is the magnitude of power leakage from one output port to another expressed as the signal amplitude difference between a given port and a reference port under matched source and load impedance conditions.

   The maximum isolation achievable with a power divider strongly depends on the impedance match presented to the input port by the external signal source. The effect of impedance mismatch is illustrated in Table 2 which lists the resultant output isolation when the input port of a two-way power divider is improperly matched.



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Mismatch "X"		Insolation in dB (Ports 1-2) as Function of Mismatch "X"			
VSWR	Return Loss dB	∞ dB*	40 dB*	30 dB*	25 dB*
1.00	∞	∞	40.0	30.0	25.0
1.03	37.0	43.0	35.2	28.2	23.9
1.05	32.0	37.0	33.0	27.2	23.3
1.10	26.0	32.0	29.4	25.1	21.9
1.15	23.0	29.0	27.0	23.5	20.8
1.20	21.0	27.0	25.0	22.3	19.9
1.30	18.0	25.0	22.5	20.3	18.3
1.5	14.0	21.0	19.2	17.6	16.1
2.0	9.5	15.5	15.1	14.1	13.0
*Inherent isolation of power divider under consideration (matched terminations)					

Table 2: The Effect of Common Port Mismatch On Device Ultimate Isolation

Amplitude Balance (or Inequality): The maximum peak-to-peak amplitude difference in dB between a reference output port and any other output port when measured at any frequency within the specified frequency range under matched impedance conditions.

4. **Phase Balance:** The maximum peak-to-peak phase difference expressed in degrees between a reference output port and any other output port when measured at any frequency within the specified frequency range under matched impedance conditions.

5. **Insertion Phase:** The phase difference measured in degrees between input and output ports measured at a specific frequency.

6. **Phase Tracking:** The difference in insertion phase between individual dividers/combiners under a variable such as temperature.

7. **VSWR:** The voltage standing wave ratio at any port assuming matched terminations at all other ports.

8. **Power Handling:** The CW power handling capacity assuming one-way transmission through the device when used as a power divider and with all output ports connected to matched terminations with a nominal VSWR out not worse than 1.2:1.

STRIPLINE POWER DIVIDERS

Merrimac stripline power dividers/ combiners are binary distribution networks typically constructed from an array of two-way hybrid dividers. Basic two-way dividers are modeled as a Split-Tee Hybrid with the odd-mode or balanced excitation internally terminated resulting in a 3-Port Hybrid. A Split-Tee Hybrid is actually a four port hybrid magic tee where the E-Port (odd-mode) excitation is internally terminated as illustrated in Figure 3.

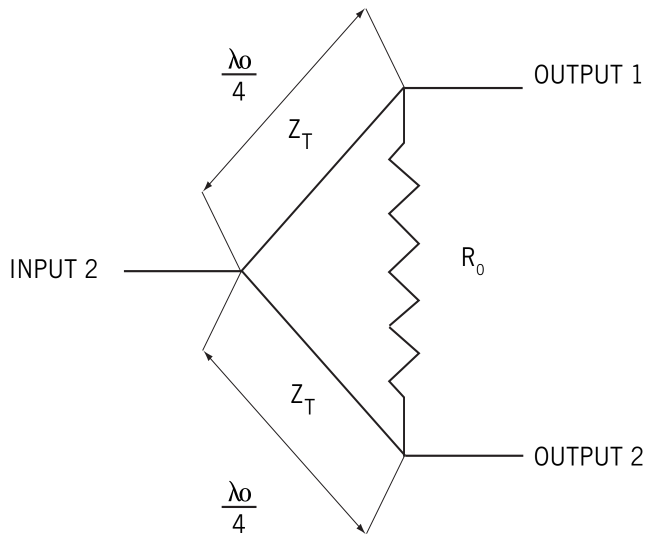

Figure 3: Split Tee Hybrid

Merrimac offers stripline binary dividers in two, four and eight-way configurations as well as direct n-way dividers for applications requiring low-loss division into three, five and seven-way output ports. All are available in various narrow-band, octave and multi-octave bandwidths from 500 MHz to 40 GHz. Most catalog models have BNC, SMA, N or K type female connectors. In addition, Merrimac has designed others in a wide variety of package configurations including in-line, T and H style output configurations.

Merrimac offers a line of ultra-wideband power dividers/ combiners for applications in wideband ECM (Electronic Counter Measures) systems and general instrumentation. Catalog models include two and four-

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way power dividers covering part or all of the 0.5 to 40 GHz band.

Merrimac will be pleased to quote on selected stock items as well as specially designed units offering higher isolation, lower insertion loss, lower VSWR and more precise phase and amplitude balance.

STRIPLINE POWER CONSIDERATIONS

Figure 4 illustrates a typical broadband power divider circuit with its internal termination junctions.

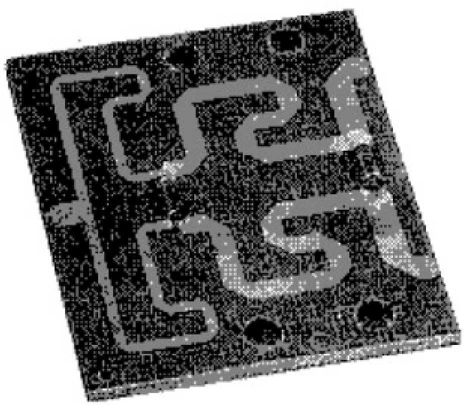

Figure 4: Typical Broadband Power Divider Circuit

The power handling capacity of in-phase power dividers/combiners is determined principally by the power dissipation capacity limits of the internal resistor termination(s) in the combiner/divider. Typically, the CW input power limit of Merrimac power dividers/combiners is approximately 6 watts assuming a load VSWR of no worse than 1.2:1.

When an application requires fail-safe operation, the divider design must allow for at least one output port being subjected to a high VSWR such as might occur with the loss of an antenna array element. Design rules require power divider performance to be appropriately derated. With one port unterminated, for example, half the output power of one of the unterminated output ports is dissipated in the divider's "outboard" terminating resistor. Fail-safe derating of typical catalog products means a maximum input power of 100 mW is permitted under these conditions. Given special design attention to the power dissipation of the load resistors, stripline dividers and combiners are inherently capable of handling considerably higher power levels.

ALTERNATIVES

For dividing and combining at higher power levels in the range of several hundred watts, the four port, 90° quadrature coupler or 180° hybrid junction is often the best option. This is because with these devices any reflected power is reflected towards an external load via the isolated port. This relieves the power dissipation constraint since the mismatch-derived power does not have to be internally dissipated as is the case with in-phase divider/combiners. A discussion of these issues is presented in Section 5 which presents Merrimac's Quadrature Couplers.

PHASE AND AMPLITUDE TRACKING

Many systems require uniform phase and amplitude characteristics. This is particularly true for multi-channel receivers, transmitters and antenna systems. Merrimac in-phase power dividers/combiners have been designed to yield very good unit-to-unit phase and amplitude tracking together with excellent transfer phase linearity and amplitude flatness. With careful selection of stock units or by special design, units can be supplied with specially matched characteristics in both the phase and amplitude domains.

STRIPLINE CONSTRUCTION TECHNIQUES

The stripline power dividers offered by Merrimac in this catalog utilize a variety of low loss dielectric circuit materials in accordance with MIL-P-13949.

SMA, N and K type connectors in accordance with the interface requirements of MIL-C-39012 are standard. Most models are fabricated using captivated connectors designed to eliminate the rotation of center conductors.

The SMA connector-to-stripline interface is typically constructed with a male-female connection within the stripline circuit. The female connection is captured with an epoxy pin while the male pin is attached to the

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circuit. This arrangement allows for thermal expansion of the connectors without stressing the circuit attachment. All connector joints to the circuit are rendered permanent by using either parallel gap welds or solder connections.

Figure 5 shows a power divider printed circuit photo artwork array that enables cost-effective production of large quantities of units. Where used, copper clad, low loss woven and non-woven PTFE materials are chemically etched at the factory maintaining close tolerances for maximum uniformity and product yield.

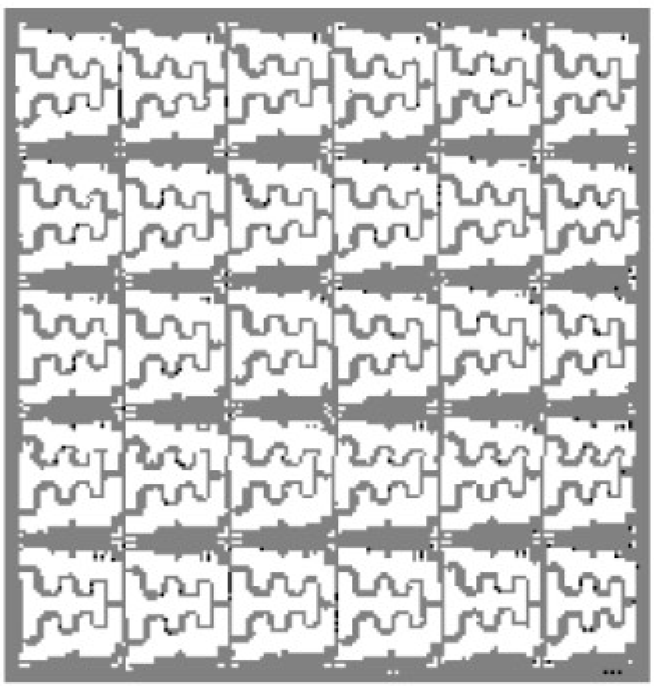

Figure 5: Stripline Photo Artwork Array

Merrimac thermally bonds circuit laminates to each other and to the circuit ground planes using a polyethylene or acrylic bond that is cured under temperature and pressure. This is extremely important for maintaining the electrical performance characteristics of the finished unit especially under conditions of high humidity.

ENVIRONMENTAL CAPABILITIES AND RELIABILITY

Merrimac provides relevant information on each product data sheet and guarantees performance to various applicable military and space specifications.

All MTBF calculations are performed in accordance with MIL-HDBK-217 procedures and can be provided at reasonable cost to aid with sub-system or end-item reliability/availability estimates. For higher levels of reliability, Merrimac can provide power dividers with Hi-Rel connectors and screened internal-terminations as an option. Special services such as temperature cycling, hi-temp bake, humidity exposure testing, thermal-vac., burn-in, shake-vibe, and more are available. Ask for a quotation meeting your special needs.