Important RF Components

Contributed to the ACAS 2016 School

John D. Fox

Applied Physics Department
Stanford University
Stanford Linear Accelerator Center
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SLAC NATIONAL ACCELERATOR LABORATORY

Outline

2 Way, or N Way, power splitters and Combiners

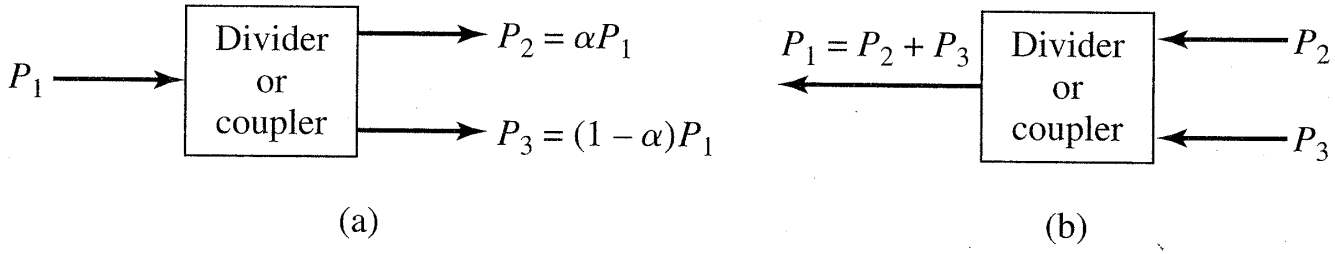


FIGURE 7.1 Power division and combining. (a) Power division. (b) Power combining

- Preserve Characteristic Impedance at each port
- What does a BNC T do?

Restsive Splitter

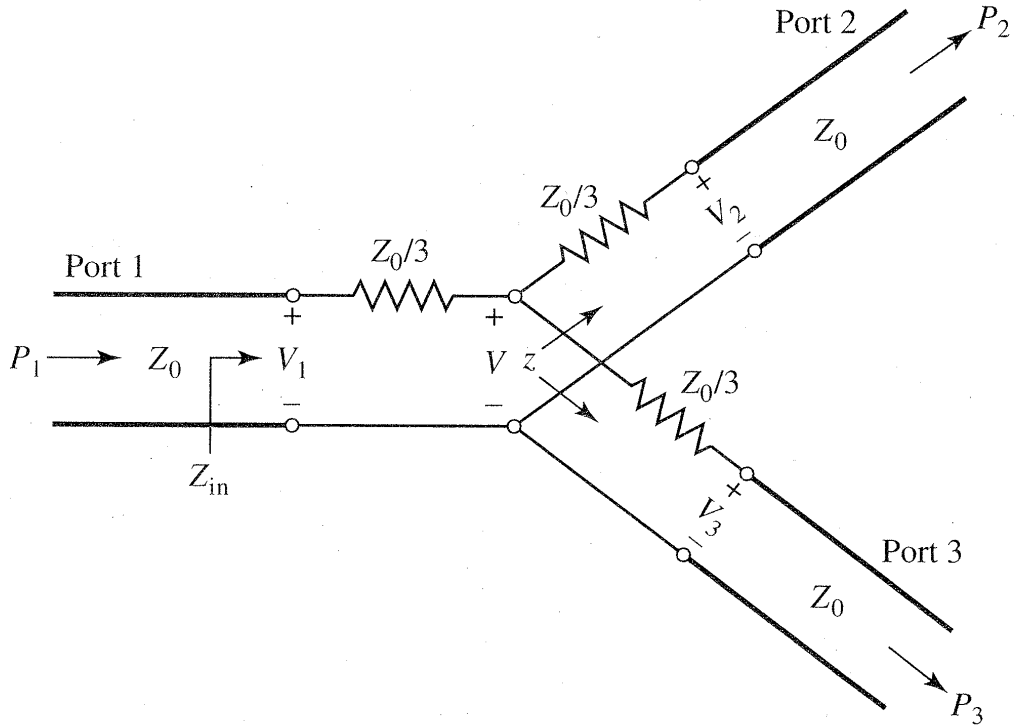


FIGURE 7.7 An equal-split three-port resistive power divider.

- Preserves Characteristic Impedance at each port
- Does it have any isolation?
- Does it have losses?

Wilkinson Power divider

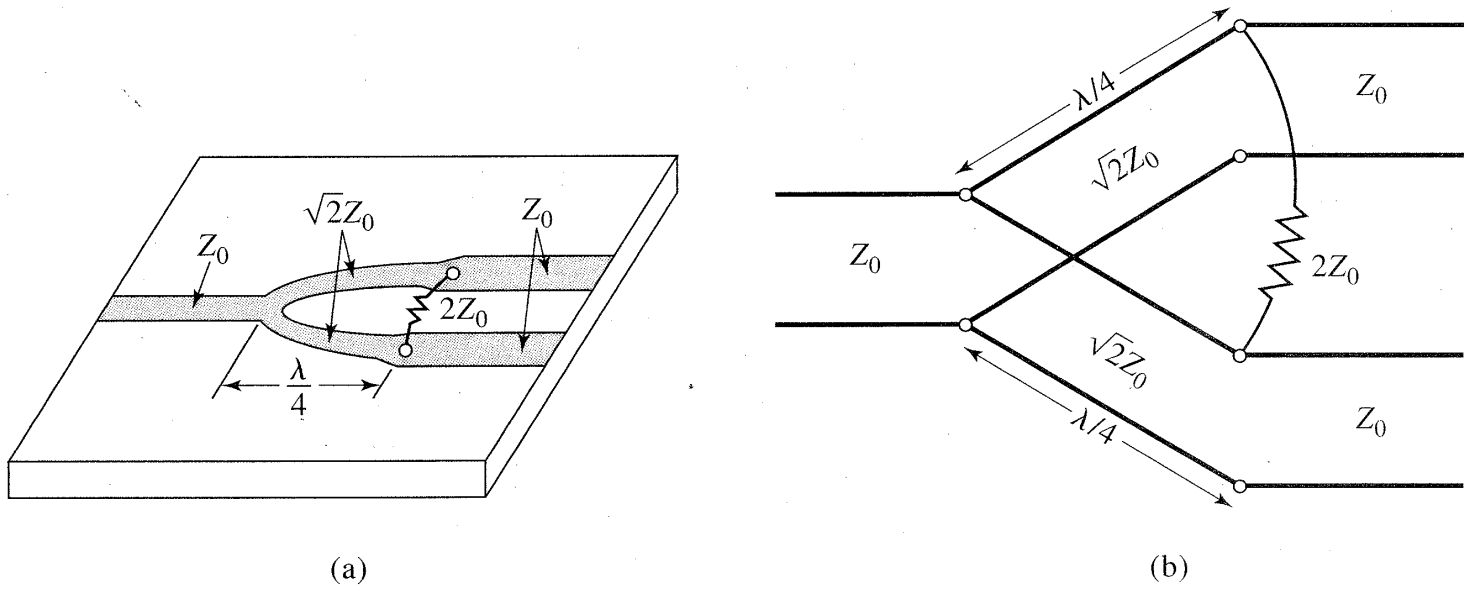


FIGURE 7.8 The Wilkinson power divider. (a) An equal-split Wilkinson power divider in microstrip form. (b) Equivalent transmission line circuit.

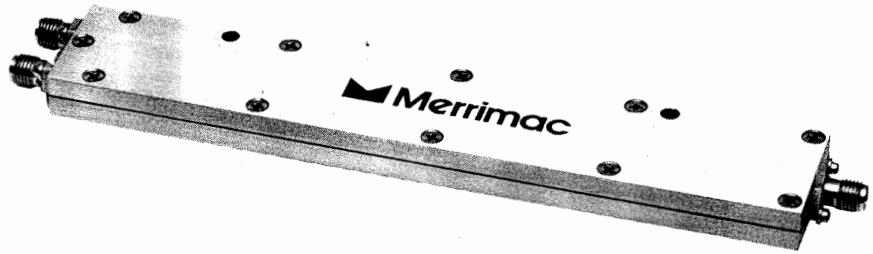
- Preserve Characteristic Impedance at each port
- Does it have losses?
- What signals go in the internal load?

Buy a 2 Way broadband

Merrimac **PDM-02S series**

- Bandwidths to 0.5 to 18.0 GHz
- Excellent Phase and Amplitude Balance
- High Isolation between Output Ports

0° POWER DIVIDER/COMBINERS, SMA
Two Way, Multi-Octave, Stripline



4.25

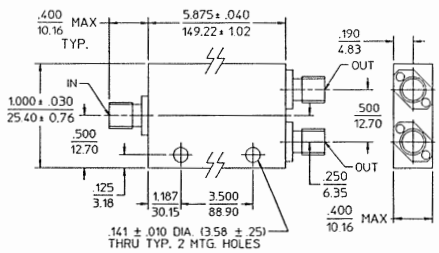
These multi-section devices are designed to provide precise in-phase division of microwave signals in three multi-octave bands up to 0.5 to 18.0 GHz. It is one of many Power Dividers developed to meet broadband ECM requirements with very tight amplitude and phase balance, and high output port isolation.

These complex designs have been developed using original analysis of stripline theory on the in-house CAD/CAM. Design variations can be realized by recalling critical parameters, which can then be readily modified for specific requirements with artwork and machining drawings being produced directly.

All MERRIMAC stripline products are designed for exceptional reliability and rigorous environments such as in uninhabited airborne specifications. Each may be supplied screened to meet specific military and space applications.

Model Number	Frequency Range GHz	Output Isolation min.	Insertion Loss max.	Phase Balance Max.	Amplitude Balance Typ.	VSWR max. In/Out	Max. Average Power with Load VSWR of 1.20:1	2.0:1	∞:1
PDM-02S-4G	0.5 to 8.0	19 dB	0.9 dB	4°	0.3 dB	1.30:1	30 W	10 W	1 W
PDM-02S-6G	1.0 to 12.4	15 dB	1.6 dB	6°	0.3 dB	1.65:1	30 W	10 W	1 W
PDM-02S-9G Advanced Specification	.5 to 18.0	18 dB	1.5 dB	8°	0.4 dB	1.35:1	30 W	10 W	1 W

Package Outl'.ie



COMMON SPECIFICATIONS

RF Impedance:	50 Ω nom.
Operating Temperature:	−55° to +85°C
Connectors:	SMA Female to meet interface requirements of MIL-C-39012
Weight, nominal:	3.5 oz (100 g)

AVAILABLE SPECIFICATIONS

Similar stripline designs of Power Dividers up to 16 ways, and for frequencies to 20 GHz are available as both custom and catalog products.

Hybrids of 2, 4 or N ports

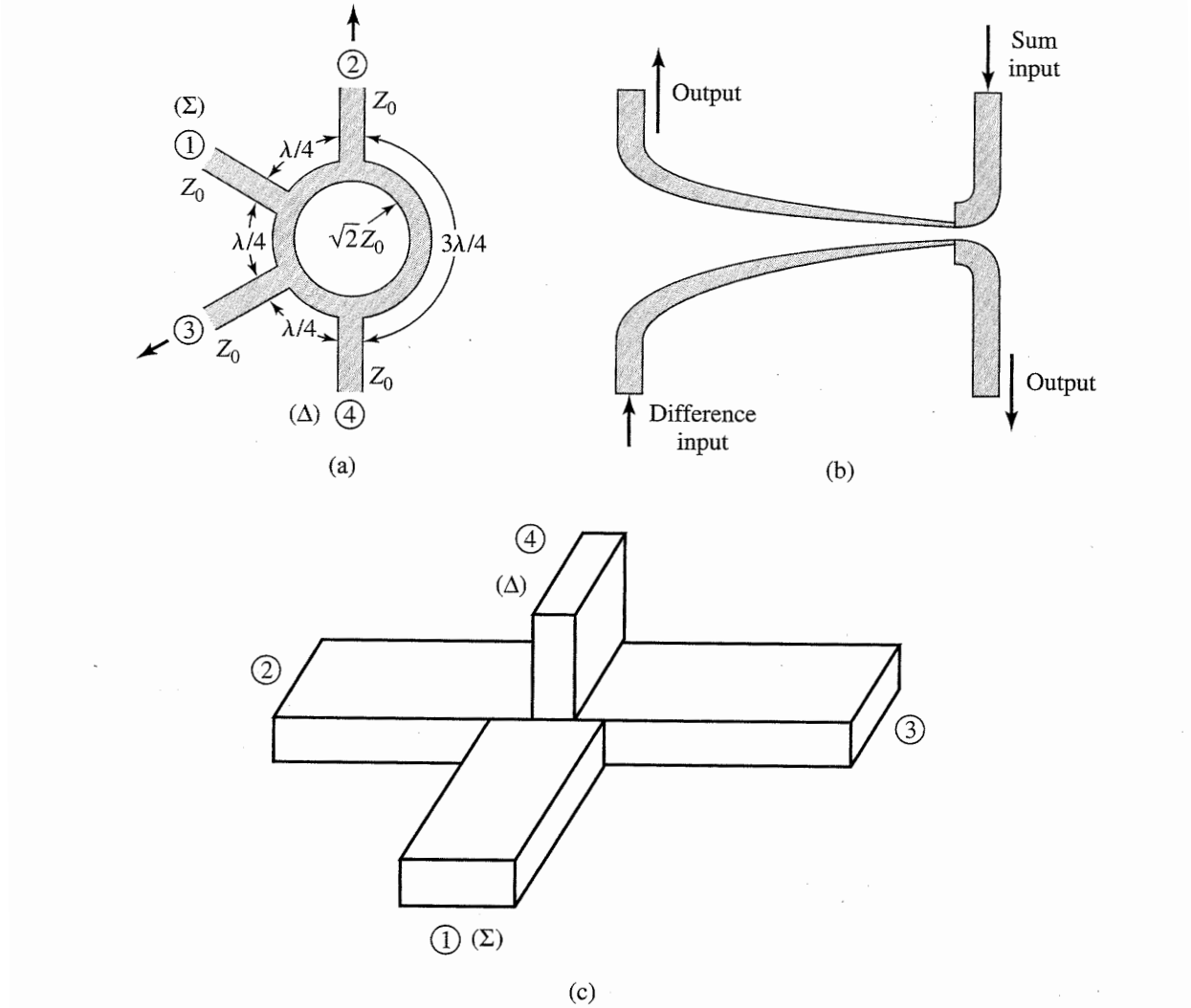
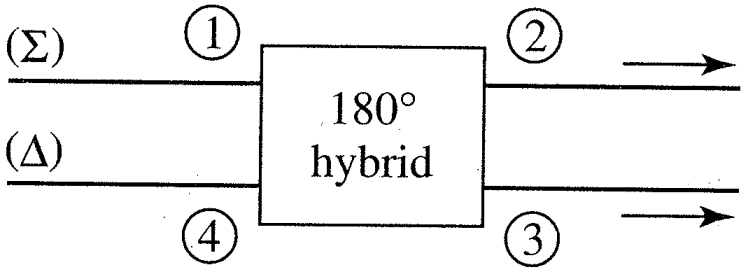


FIGURE 7.43 Hybrid junctions. (a) A ring hybrid, or *rat-race*, in microstrip or stripline form. (b) A tapered coupled line hybrid. (c) A waveguide hybrid junction, or *magic-T*.

2 way 180 degree ΔΣ hybrid



Symbol for a 180° hybrid junction.

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}.$$

- Preserve Characteristic Impedance at each port
- Does it have losses?
- Can it Add and Subtract?

90 Degree Hybrid

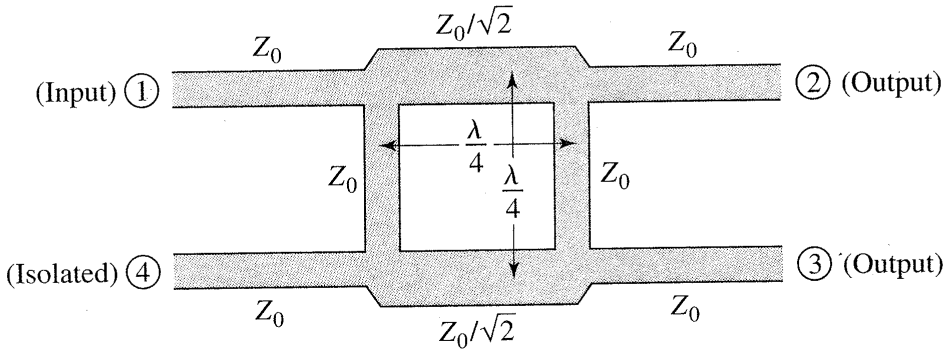


FIGURE 7.21 Geometry of a branch-line coupler.

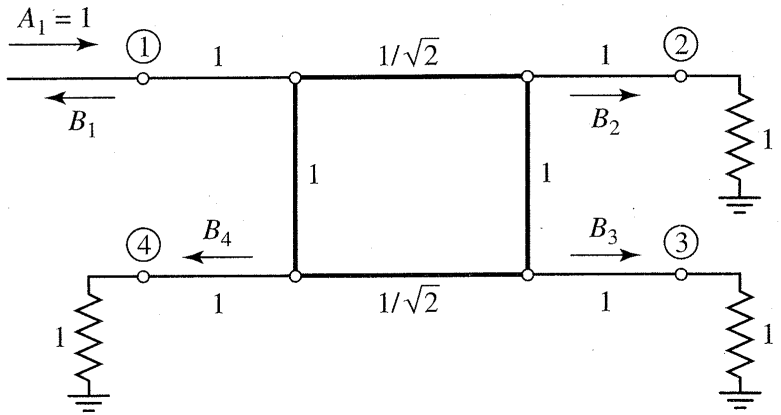


FIGURE 7.22 Circuit of the branch-line hybrid coupler in normalized form.

- What Bandwidth does this work over?
- Does it have losses?
- What signals go to port 4??

90 Degree Hybrid

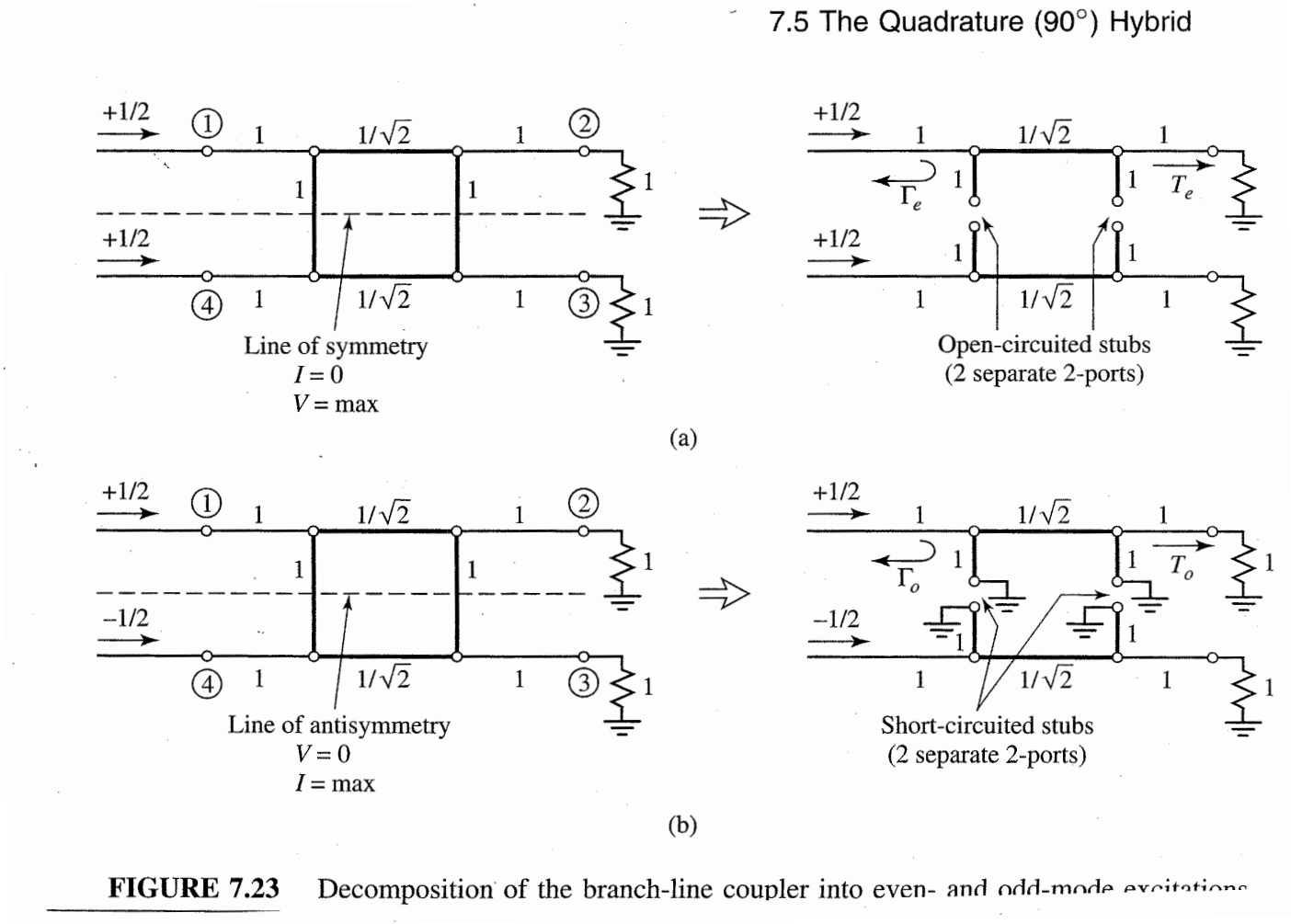


FIGURE 7.23 Decomposition of the branch-line coupler into even- and odd-mode excitations

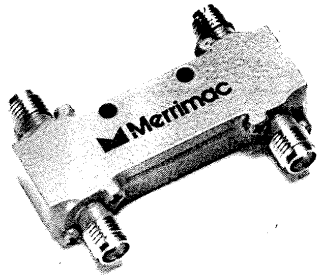
- What Bandwidth does this work over?
- Does it have losses?
- What signals go to port 4??

Buy a 90 Degree Hybrid

Merrimac

QHM-2M/QHM-3M series

90° POWER DIVIDER/COMBINER, SMA
Low Cost, Stripline Hybrid Couplers



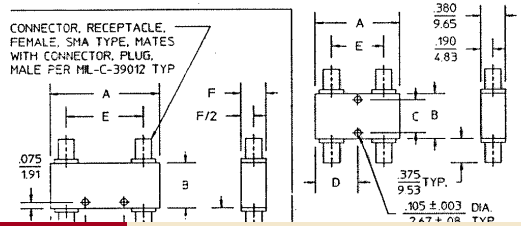
- 500 MHz to 18 GHz Frequency Range
- Octave and Multi-Octave Models
- Low Insertion Loss and VSWR

Model Number	Frequency Range, GHz	*Coupling Loss, dB	Frequency Sensitivity	Isolation dB min.	Power Avg.	Power Peak	VSWR max	Weight oz.(g)	Outlin Ref
QHM-2M-.75G	0.5 - 1.0	3.1 ± 0.6	± 0.5 dB	28	50 W	3 kW	1.10:1	1.2 (34)	4
QHM-2M-1.5G	1.0 - 2.0	3.1 ± 0.6	± 0.5 dB	28	50 W	3 kW	1.10:1	0.85 (24)	5
QHM-2M-3G	2.0 - 4.0	3.1 ± 0.6	± 0.5 dB	22	50 W	3 kW	1.20:1	0.65 (18)	1
QHM-2M-4G	2.6 - 5.2	3.1 ± 0.6	± 0.5 dB	20	50 W	3 kW	1.25:1	0.60 (17)	2
QHM-2M-6G	4.0 - 8.0	3.2 ± 0.7	± 0.5 dB	18	50 W	3 kW	1.25:1	0.60 (17)	2
QHM-2M-9G	6.0 - 12.4	3.2 ± 0.7	± 0.5 dB	18	50 W	3 kW	1.30:1	0.60 (17)	2
QHM-2M-12G	7.5 - 16.0	3.4 ± 0.9	± 0.6 dB	15	50 W	2 kW	1.40:1	0.65 (18)	3
QHM-2M-15G	12 - 18.0	3.4 ± 1.0	± 0.7 dB	15	50 W	1 kW	1.40:1	0.65 (18)	3
QHM-3M-5G	2.0 - 8.0	3.3 ± 0.8	± 0.4 dB	17	30 W	3 kW	1.30:1	1.65 (46)	6
QHM-3M-8G	4.0 - 12.4	3.3 ± 0.8	± 0.4 dB	17	20 W	2 kW	1.35:1	1.1 (30)	7

*Coupling Loss includes Insertion Loss and Frequency Sensitivity

Package Outline

OUTLINE	A	B	C	D	E	WT. OZ. (G)
1	1.150 29.21	.500 12.70	.314 7.98	.580 14.73	.660 16.76	.63 (18)
2	1.000 25.40	.500 12.70	.314 7.98	.500 12.70	.500 12.70	.60 (17)
3	1.000 25.40	.580 14.73	.392 9.96	.500 12.70	.500 12.70	.63 (18)



The octave band QHM-2M series an multi-octave QHM-3M series of Hybri Couplers have been designed using miniatur stripline construction to achieve high isolatio and low VSWR. They may be used in a wid variety of applications requiring equal divisio or combination of signals 90° out of phase, suc as in mixers, modulators and phase shifters.

MERRIMAC Hybrid Couplers ar designed to meet the requirements MIL-P-23971, and may be ordered i accordance to this and other simila specifications. All units are available screene for use in space and harsh environments, wher reliability is critical.

Directional Coupler

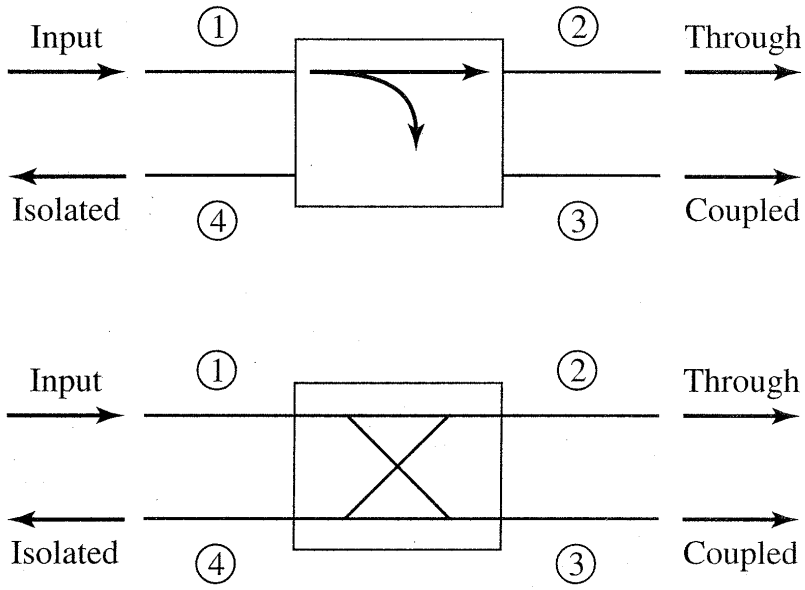


FIGURE 7.4 Two commonly used symbols for directional couplers, and power flow conventions.

- What Bandwidth does this work over?
- Does it have losses?
- What happens if you drive port 3?

Even/Odd Analysis of the two port coupler

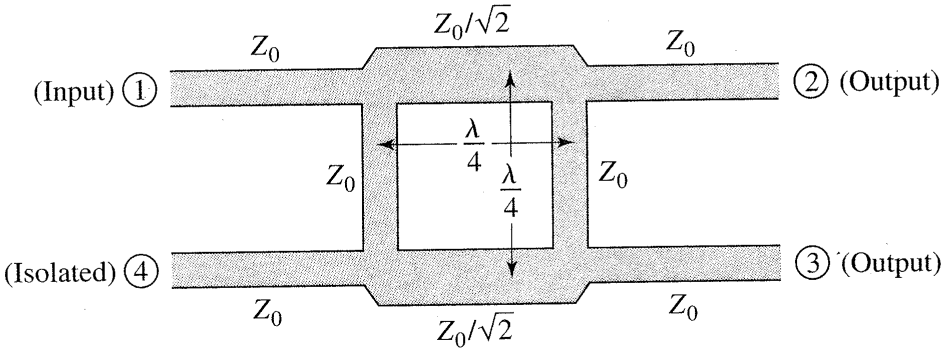


FIGURE 7.21 Geometry of a branch-line coupler.

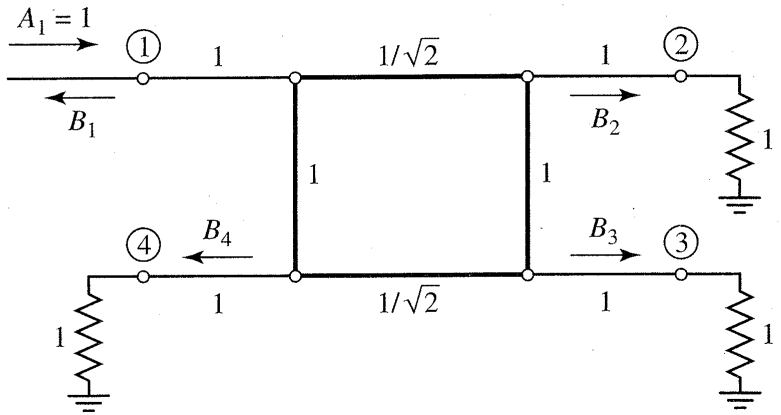


FIGURE 7.22 Circuit of the branch-line hybrid coupler in normalized form.

- What Bandwidth does this work over?
- Does it have losses?
- What signals go to port 4??

Microstrip Directional Coupler

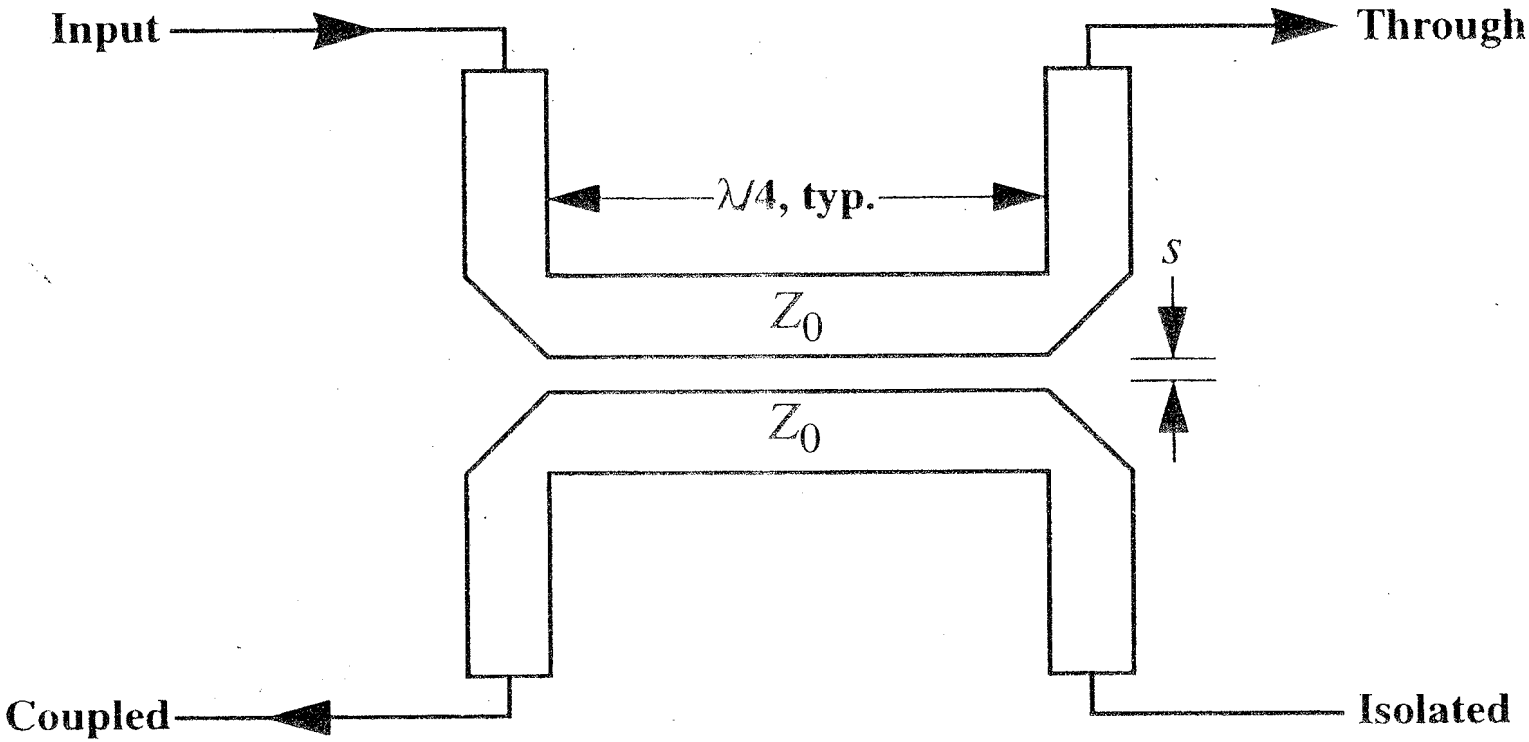
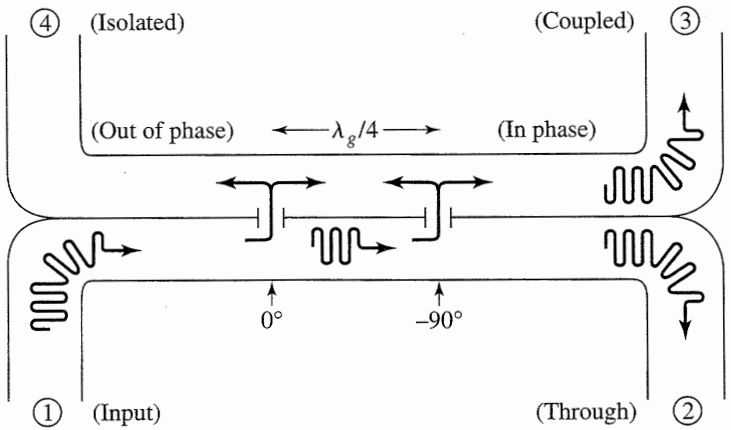


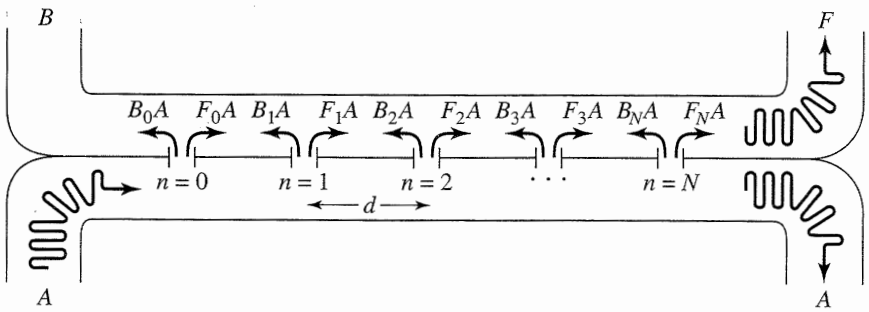
FIGURE 7.46. Classical microstrip directional coupler

- What Bandwidth does this work over?
- Does it have losses?
- What determines the coupling strength?

Bethe-Style Waveguide Coupler



Basic operation of a two-hole directional coupler.



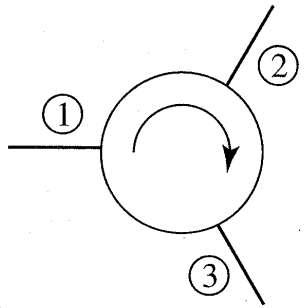
7.19 Geometry of an $N + 1$ hole waveguide directional coupler.

- What Bandwidth does this work over?
- What is the advantage of lots of holes?

Circulators

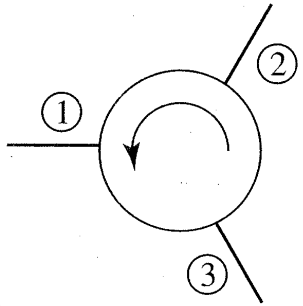
$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{12} & 0 & S_{23} \\ S_{13} & S_{23} & S_{33} \end{bmatrix}. \qquad 7.7$$

$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



(a)

$$[S] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$



(b)

FIGURE 7.2 The two types of circulators and their $[S]$ matrices. (The phase references for the ports are arbitrary.) (a) Clockwise circulation. (b) Counterclockwise circulation.

- What Bandwidth does this work over?
- Does it have losses?
- How does this work?

An Example - the Telephone Hybrid

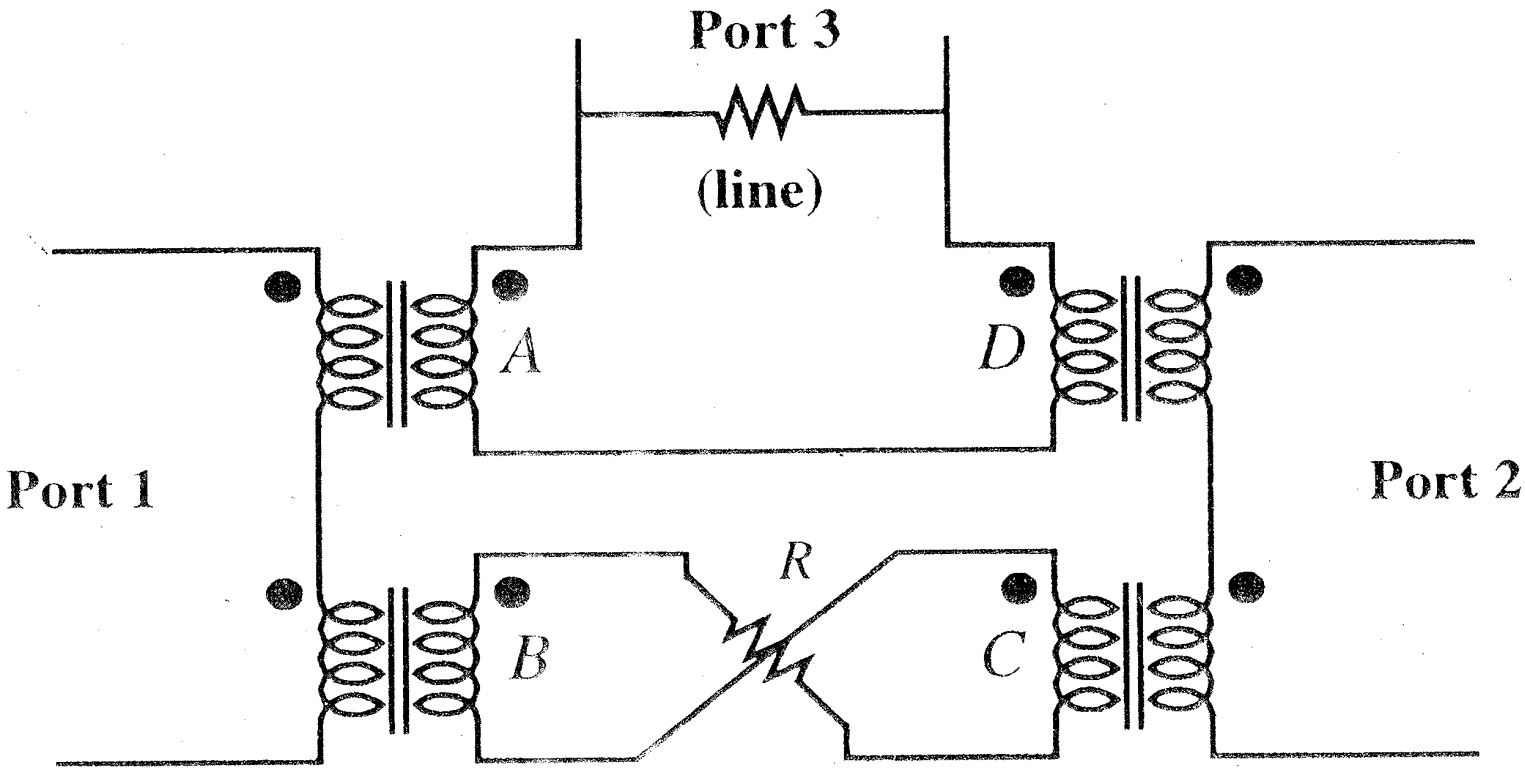


FIGURE 7.31. Classic telephone hybrid[30]

- Why do you want this in a telephone?
- What signals go on each port?

Giving Credit, where Credit is Due

- Thanks to David Pozar, *Microwave Engineering*
- Thanks to Tom Lee *Planar Microwave Engineering*
- For the use of their figures in this talk
- Both have excellent books
- Thanks to Merrimac Corporation for the old catalog figures