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Power Dividers, Couplers and Combiners

A Webinar Presented by

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Of

Besser Associates, Inc.

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Overview

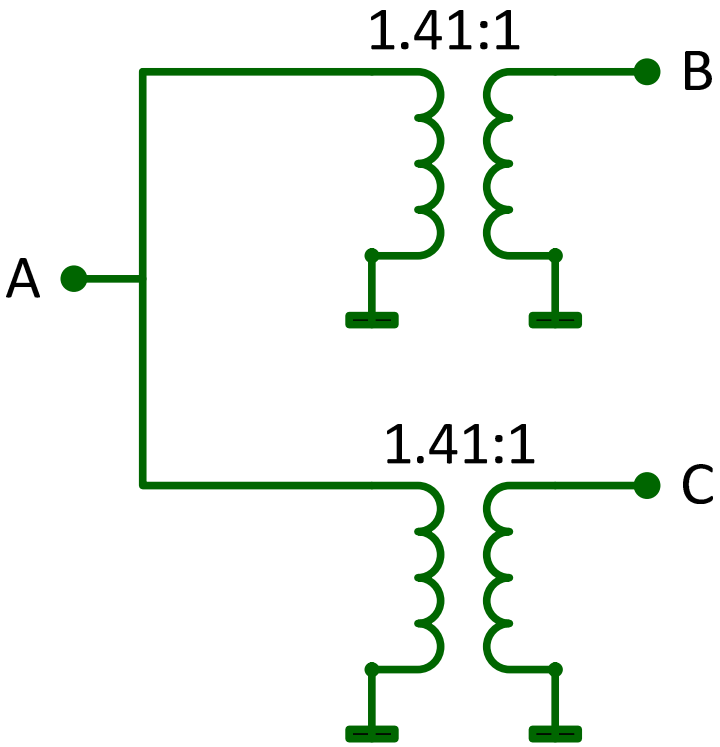
- Power dividers, combiners and directional couplers are passive structures that divide RF input power among several outputs or combine power from several inputs.
- Power Dividers and Combiners
  - Used to split input power into roughly equal outputs, or vice-versa.
- Directional Couplers
  - Used to sample a fraction of input power and/or to separate forward and reverse traveling waves.

Power Dividers/Combiners

- Goal: Distribute power from one input among several outputs, or combine power from several inputs to one output.
- Problems for RF and microwave designs
  - Impedance match
  - Isolation
  - Phase relationships among signals

Transformer Power Dividers

- Turns ratio of $\sqrt{2}$ doubles the impedance connected at B or C.
- Useful to divide or combine two signals.
- Frequently made using 90° sections of transmission line.
- Limitations
  - Matched in even mode only (same voltage at ports B and C).
  - B and C are not isolated.



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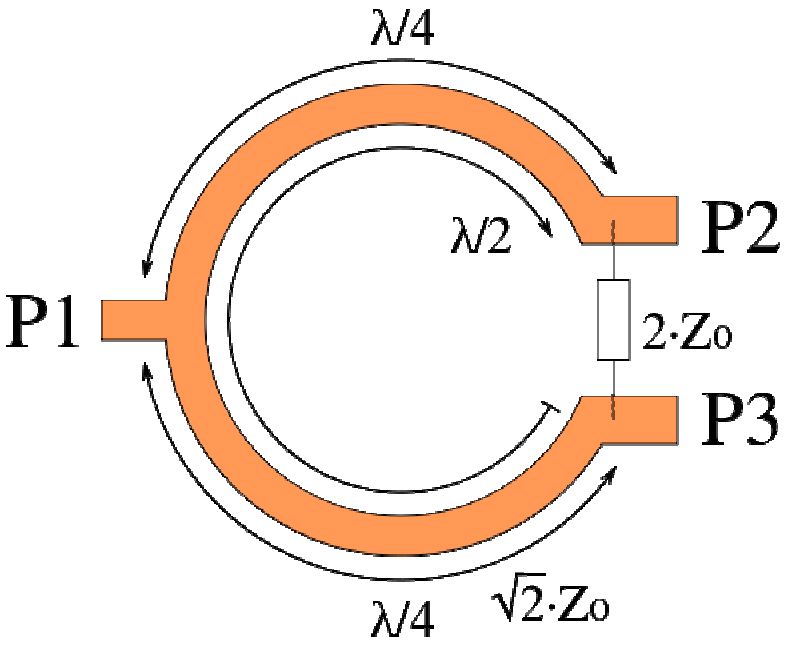
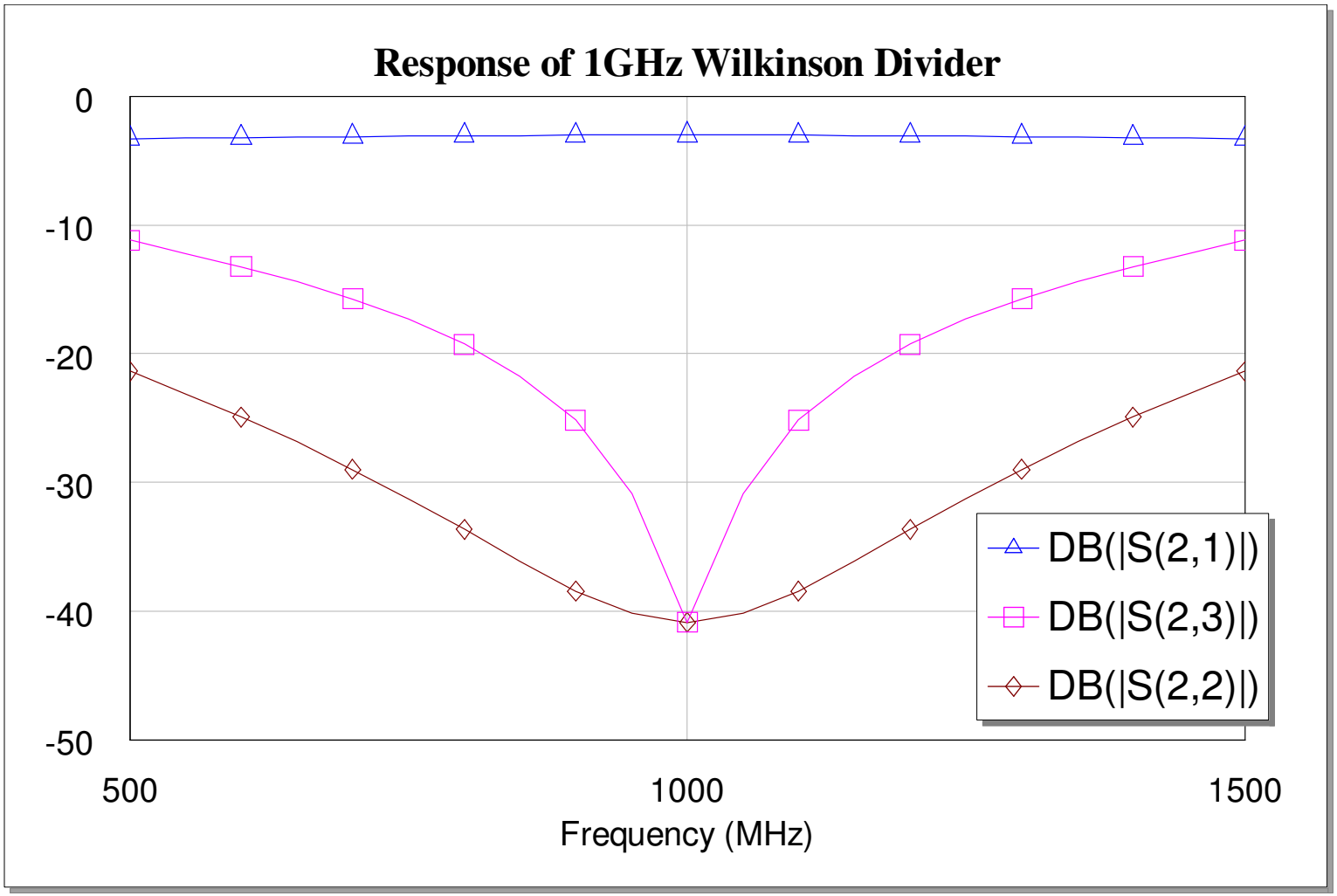
Adding Isolation: Wilkinson Divider

- When the signals at P2 and P3 are the same, the resistor has no effect.
- When P2 and P3 are 180º out of phase the power is taken up by the resistor.
- All ports are matched, and P2 and P3 are isolated from each other.



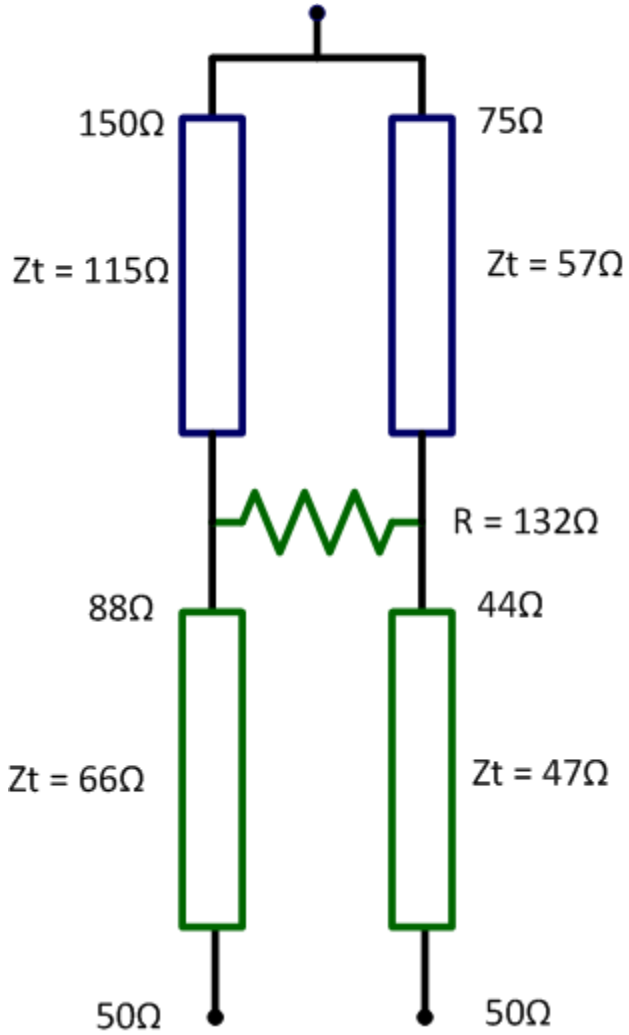


Unequal Power Division is Possible

- Transformed values must combine in parallel to 50Ω.
- Power division is inverse to the transformed impedances.
- Example:
  - Transform 50Ω loads at P2 and P3 to 150Ω (P2) and 75Ω (P3).
  - 1/3 of input power goes to P2 and 2/3 to P3.
- But the output voltages at are unequal, so we can't add an isolation resistor like before.

2:1 Divider with Isolation

- An isolation resistor requires equal voltage on both sides of the divider.
- Equal voltages with 2:1 power ratio implies 2:1 impedance ratio.
- Transform impedance in two steps:
  - 50Ω (at bottom) to intermediate levels with 2:1 ratio.
  - From there to 75 and 150Ω (at top).
  - Resistor value is the sum of the intermediate impedances.



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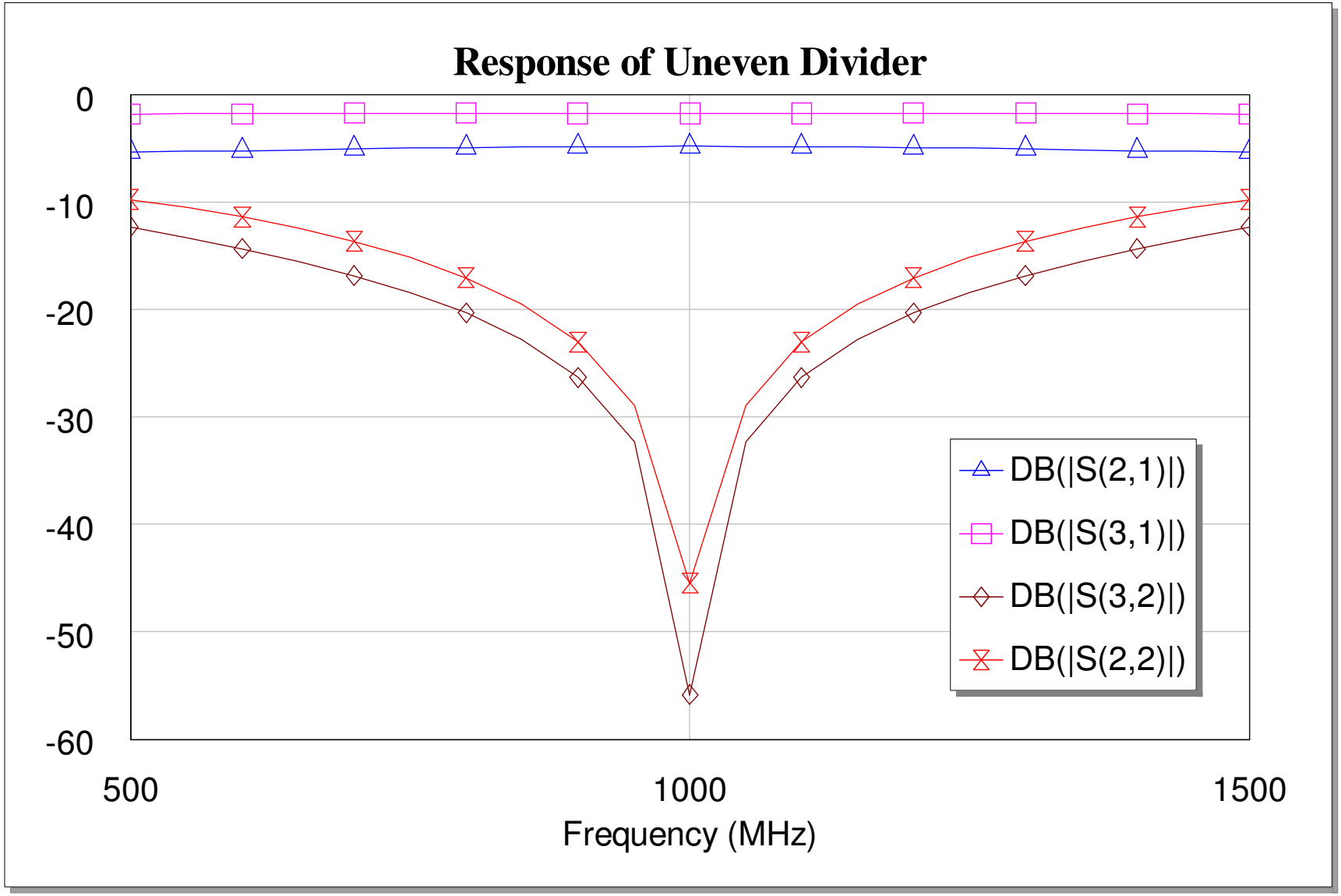

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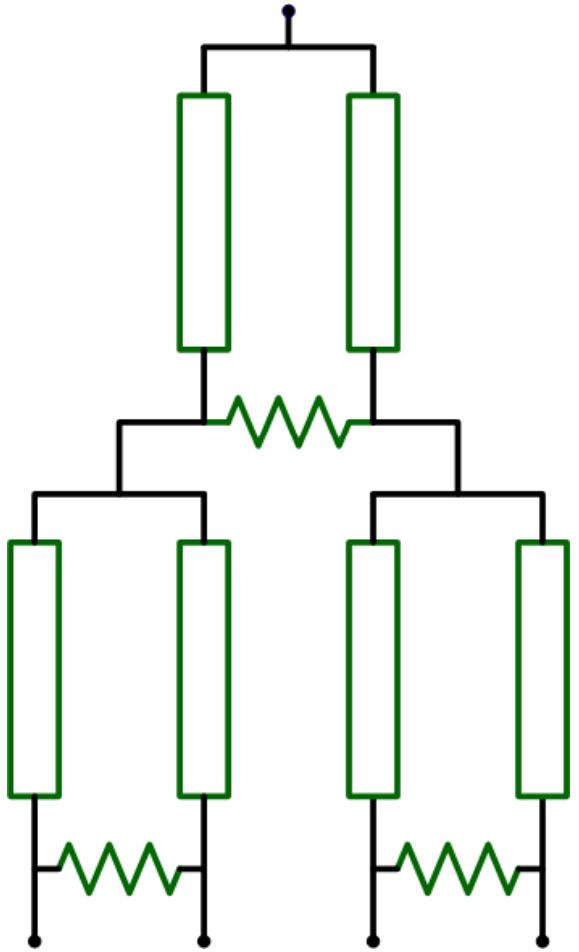
N-Way Power Dividers

- One-to-many:
  - N outputs can come together at one input using transformers that map Zo loads to N Zo at input.
  - If N > 2, it's impossible to connect isolation resistors in a 2-dimensional network.
- Two-Way Steps:
  - If N is a power of 2, branch out with Wilkinson dividers.
  - If N is not a power of 2, it still may be possible to use unequal 2-way dividers and achieve high isolation.



http://www.microwaves101.com/downloads/Robots_versus_Dinos.pdf

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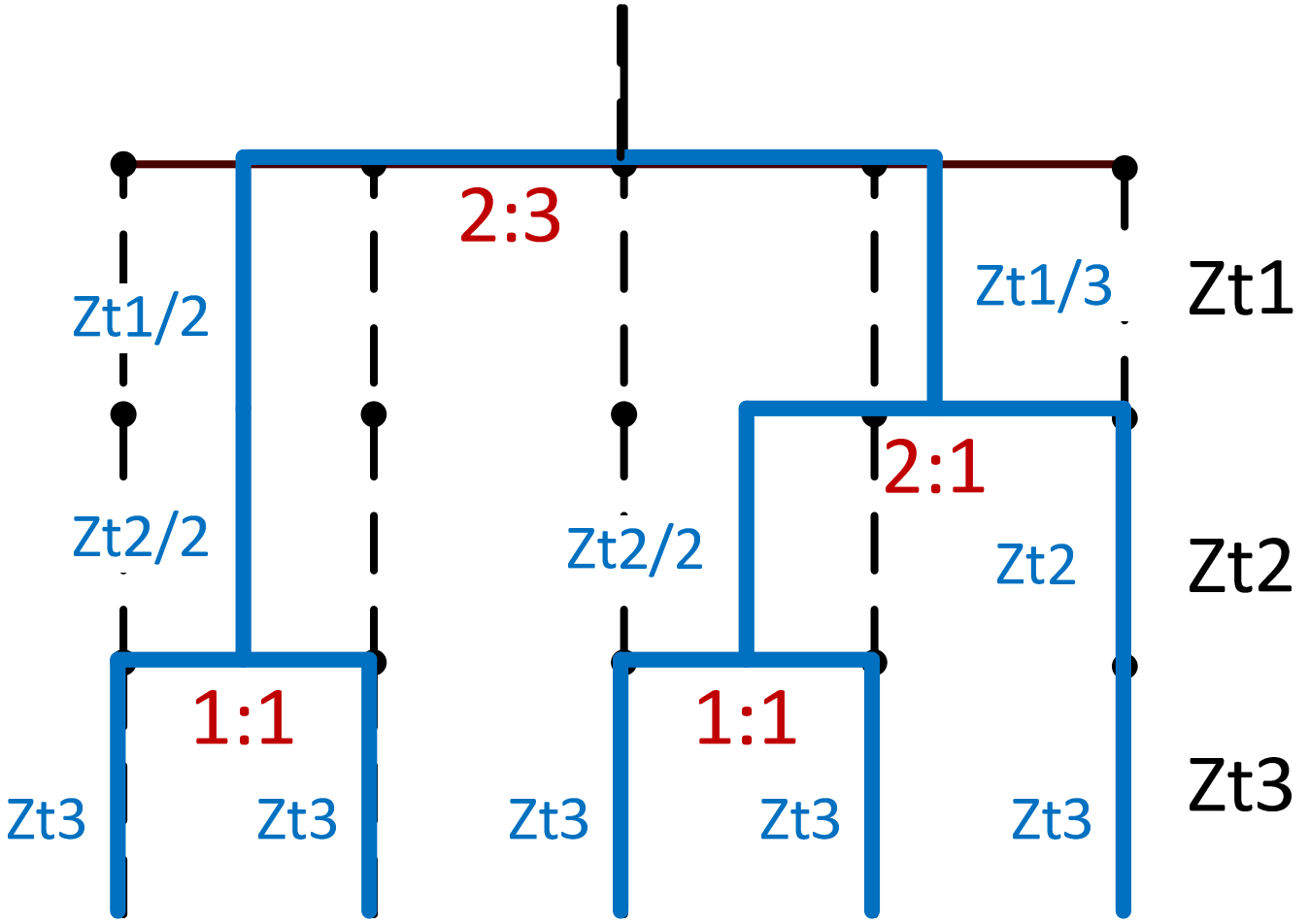
5-Way Power Divider



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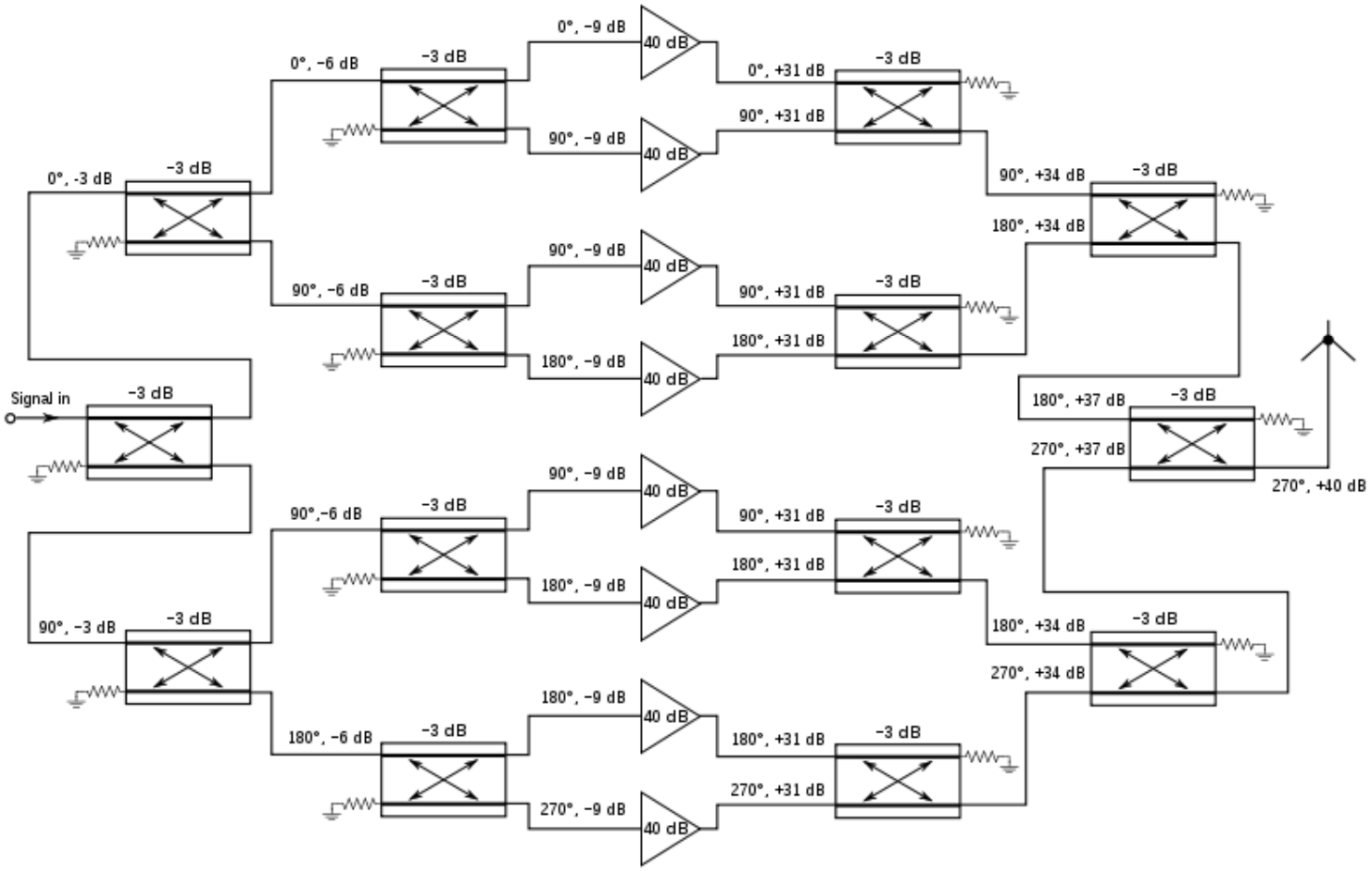
Power Combiners

- Power combiners have N inputs and one output.
- Often used to
  - Combine the outputs of several amplifiers.
  - Combine received signals from several antenna elements.
- Biggest difference is in the power rating of the isolation resistors.
  - Power divider: Resistors dissipate power if the loads are reflective. A low power rating is often ok.
  - Combiner: Resistors dissipate power if the sources are not balanced in magnitude and phase. A large power rating is often required.

Dividing and Combining in a Power Amplifier

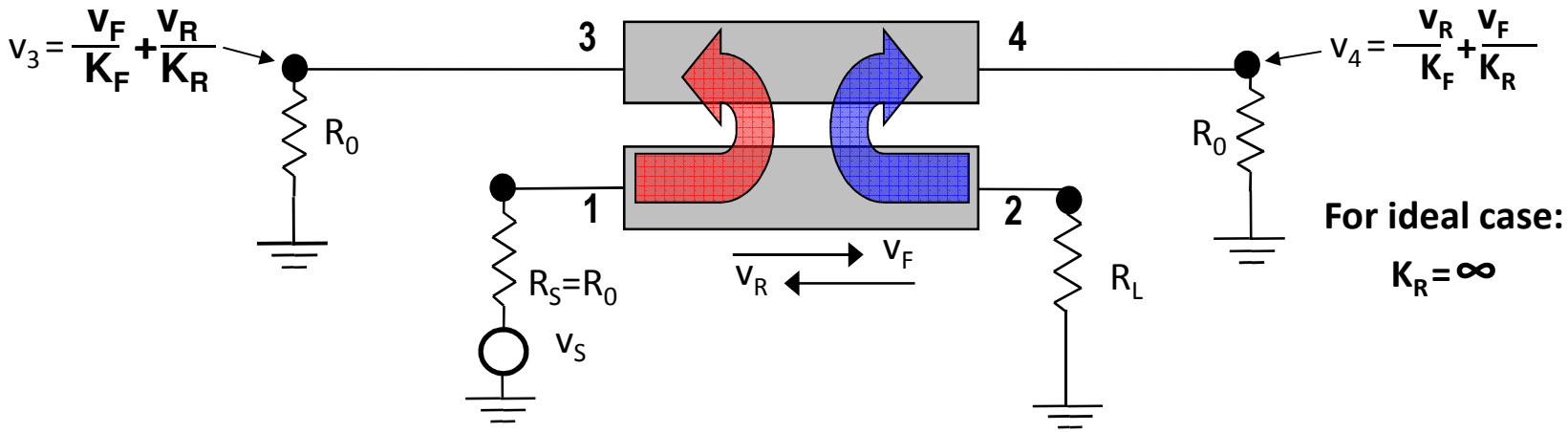


Directional Couplers

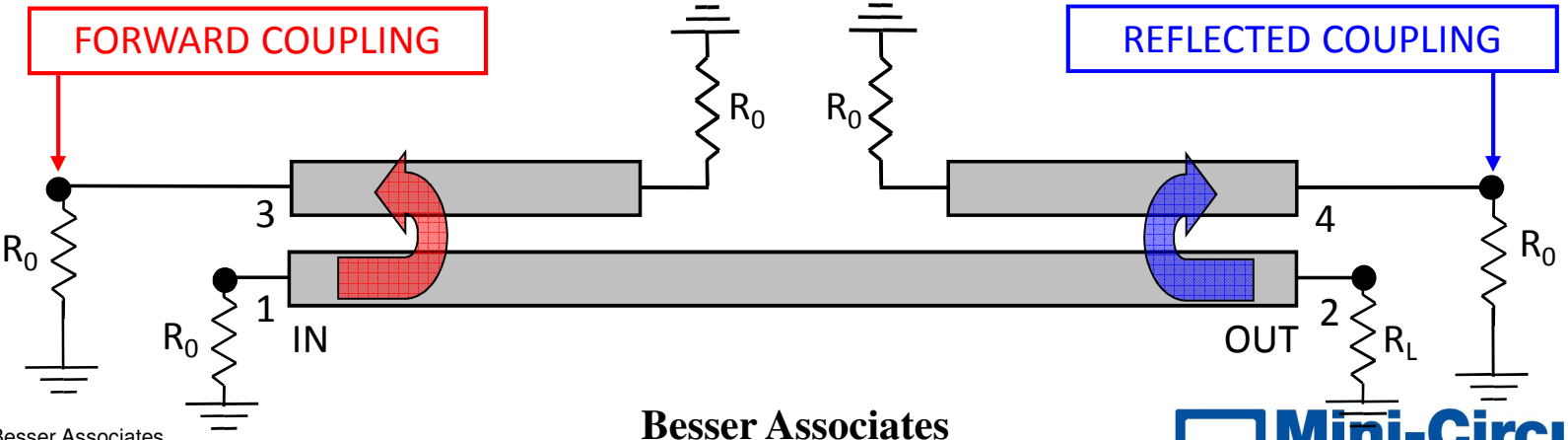
- Directional couplers have an arrangement of two transmission lines so that energy can "leak" from one line to the other.
- Often used to sample off a small portion of the signal power.
- Couplers have a directional property that is useful in many measurements.

Directional Couplers

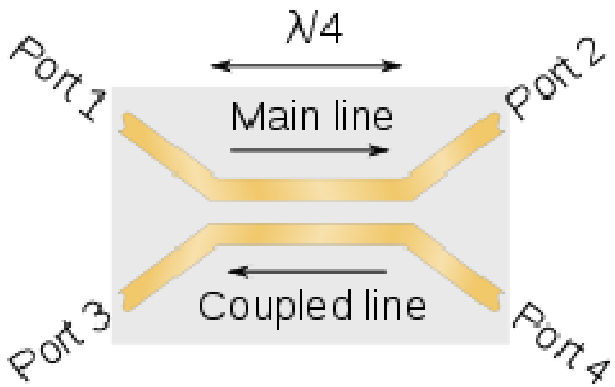
•Forward and reverse traveling waves can be observed by the use of a directional coupler.



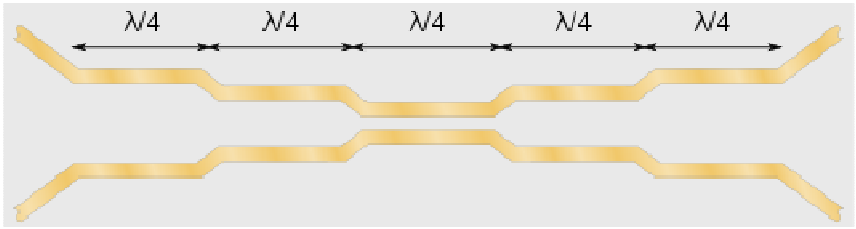
The dual-directional coupler is two directional couplers connected back-to-back to minimize "leakage" between Ports 3 and 4.



Couplers in Microstrip or Strip Line



- Operating band is centered where the sections are 90º long.



- Multi-section coupler has wider bandwidth.

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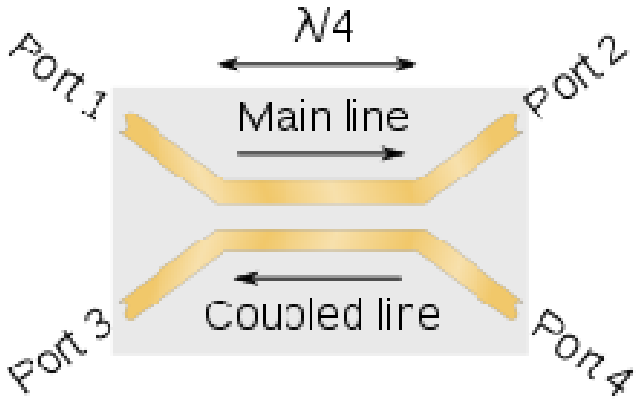
Coupler Specifications

- With ports numbered as in previous slides, coupler specifications are
  - Loss:
    input pwr at 1 / output pwr at 2
  - Coupling:
    input at 1 / output at 3
  - Isolation:
    input at 1 / output at 4
  - Directivity:
    Isolation / Coupling
- Usually all four of these are expressed in dB.



Measuring Reflections

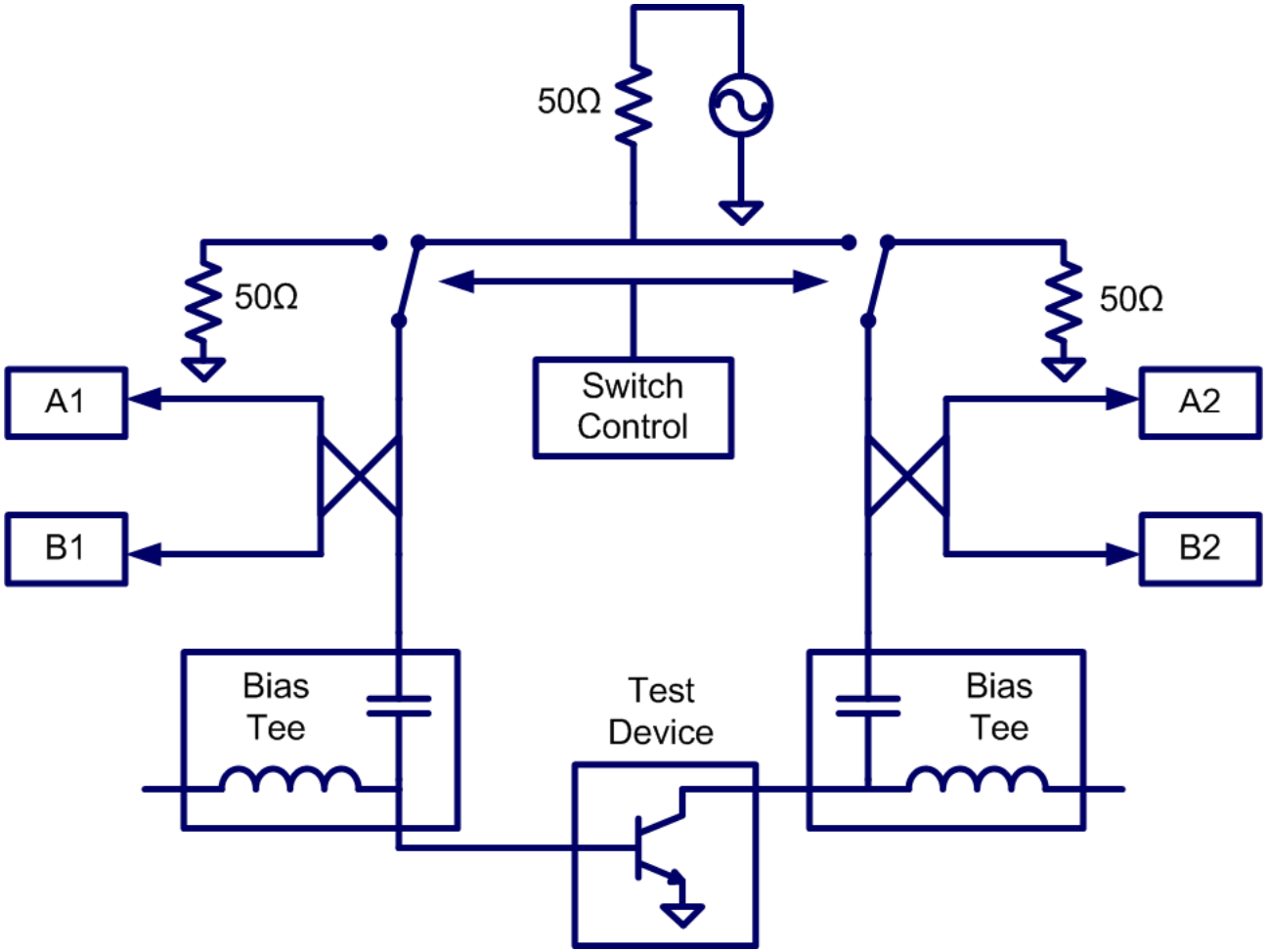
- Connect an unknown load at port 2 and send 0dBm into port 1. Assume low loss.
- A sample of reflected power from port 2 appears at port 4.
- Power of reflection sample:

  0dBm – Return Loss – Coupling
- Power leaking from 1 to 4:

  0dBm – Isolation
- Compare the sample to the leakage:

  Sample - Leakage = Directivity – Return Loss

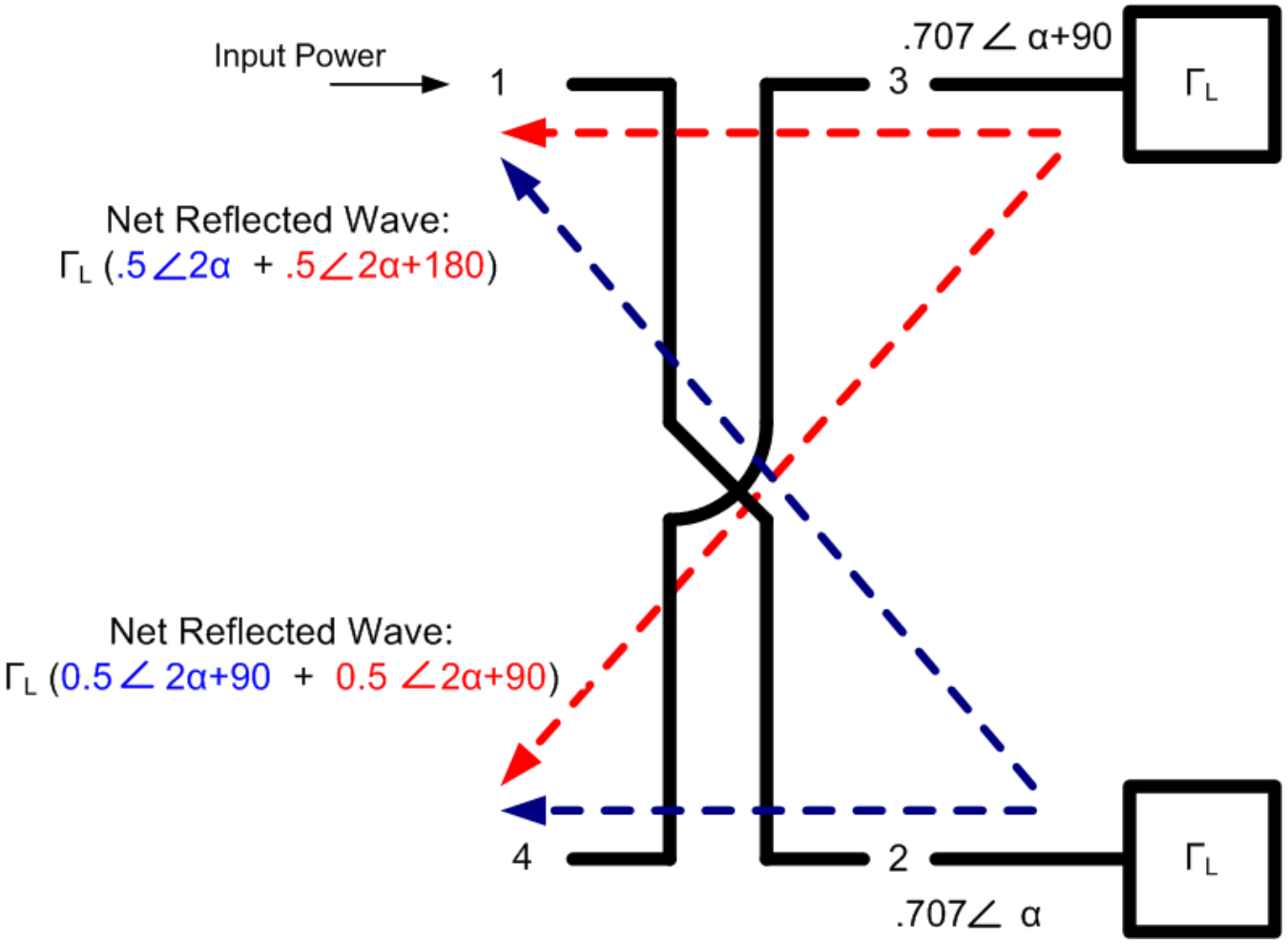
Network Analyzer System



Using Phase Relationships

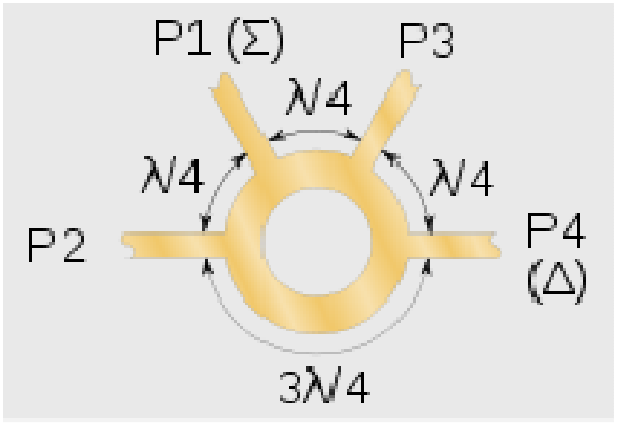
- In many couplers there is a 90º (quadrature) phase relationship between the through and coupled paths.
  - "Balanced amplifiers" use 3dB quadrature couplers to cover up input and output mismatch.
- Power dividers have definite phase relationships between the two outputs.
  - Usually 0º or 180º.
  - Can add a length of line to one side of a divider to make this 90º, 270º, etc.
  - Useful in mixers, phased arrays, etc.

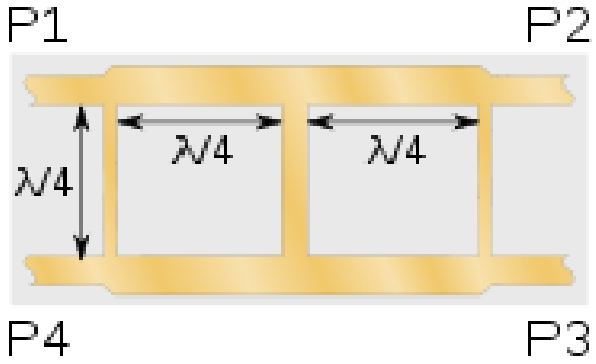
Using a 3dB Quadrature Coupler



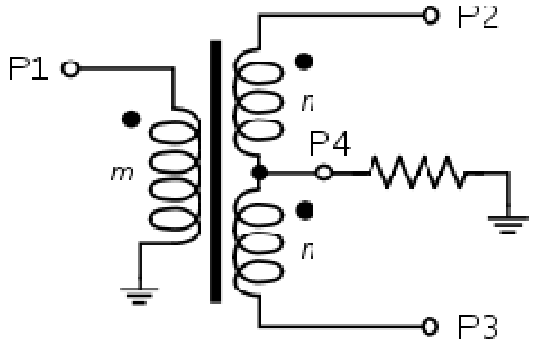
Other Phase Relationships

- Hybrid ring ("rat race") coupler
  - Input at P1 divides between P2 and P3 with equal phase.
  - Input at P4 divides between P2 and P3 with 180º phase difference.
  - P1 and P4 are isolated.
- Branch line coupler
  - Line sections are 90º long at center frequency.
  - Input at P1 divides between P2 and P3 with 90º phase difference.
  - Two-section coupler shown.

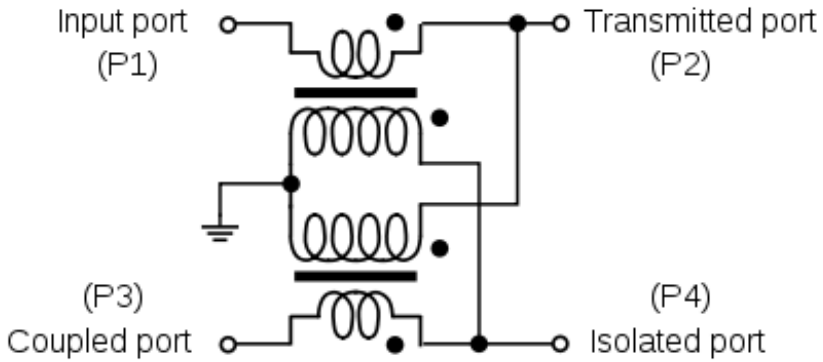




Dividers and Couplers Made from Transformers



- Transformer with center-tapped secondary can act as a 180^{o} power divider.



- Cross-coupled transformers form a directional coupler.

http://michaelgellis.tripod.com/direct.html

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