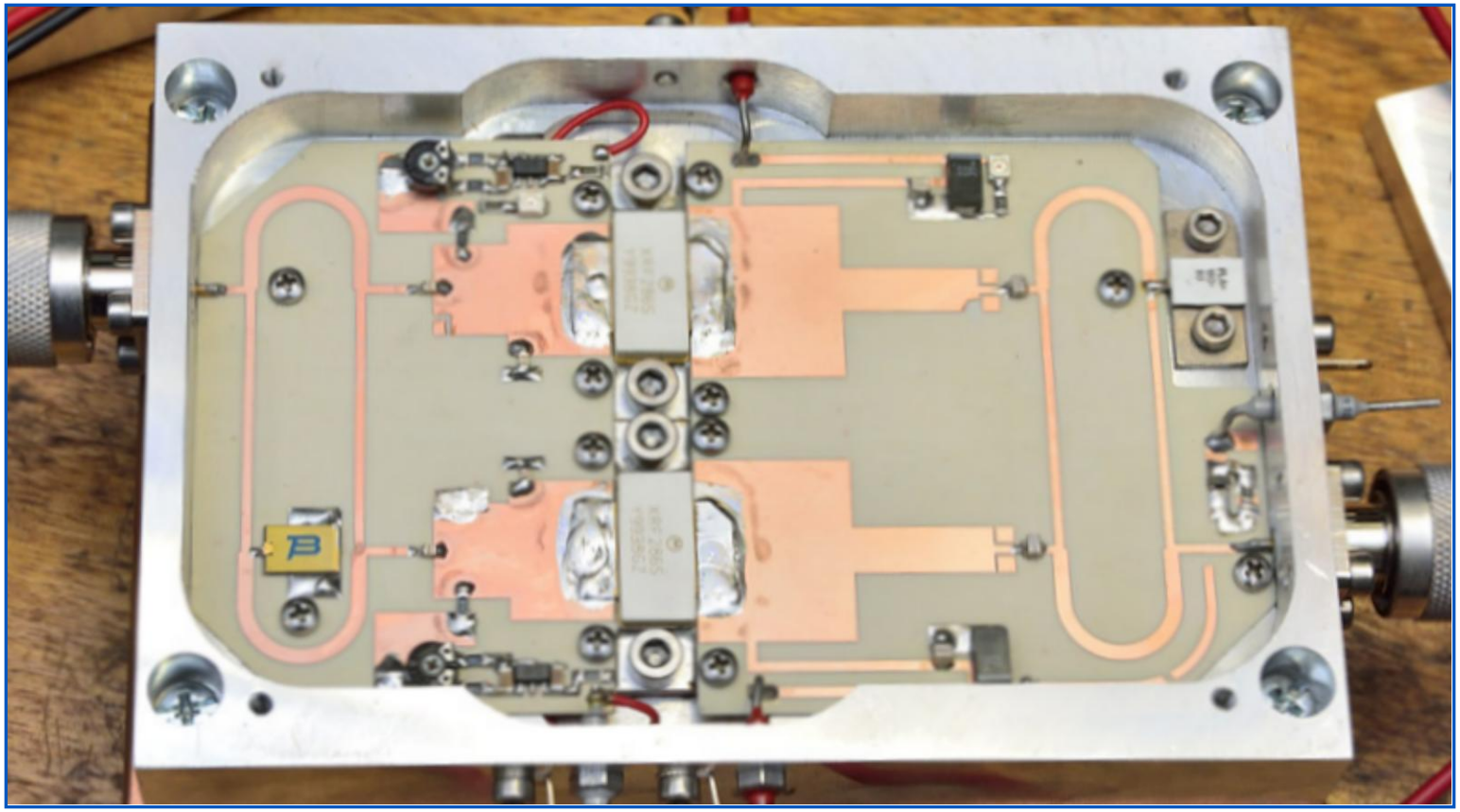
QUADRATURE (90°) HYBRIDS



K5TRA

BENEFITS FROM QUADRATURE HYBRIDS

- Quadrature split to identical loads has 1:1 input VSWR *regardless of the mismatch of those loads*
- Matched variable attenuators, variable phase shifters and negative resistance amplifiers can be realized
- Load sensitivity of combined amplifiers is reduced
- Reverse IMD performance is improved over individual amplifiers

TYPES of QUADRATURE HYBRIDS

- Coupled transmission lines (directional couplers)
- Branch-line coupler (non-coupled lines)
- Lumped ‘equivalent’ representations of coupled-line and branch-line couplers
- All have common properties:
  - Input signal is split between two output ports (-3 dB each)
  - Phase difference between output ports is 90°
  - A fourth port is provided for coupling to opposite 90° rotation. This is the hybrid isolate port.

COUPLED LINES - SYMMETRIC

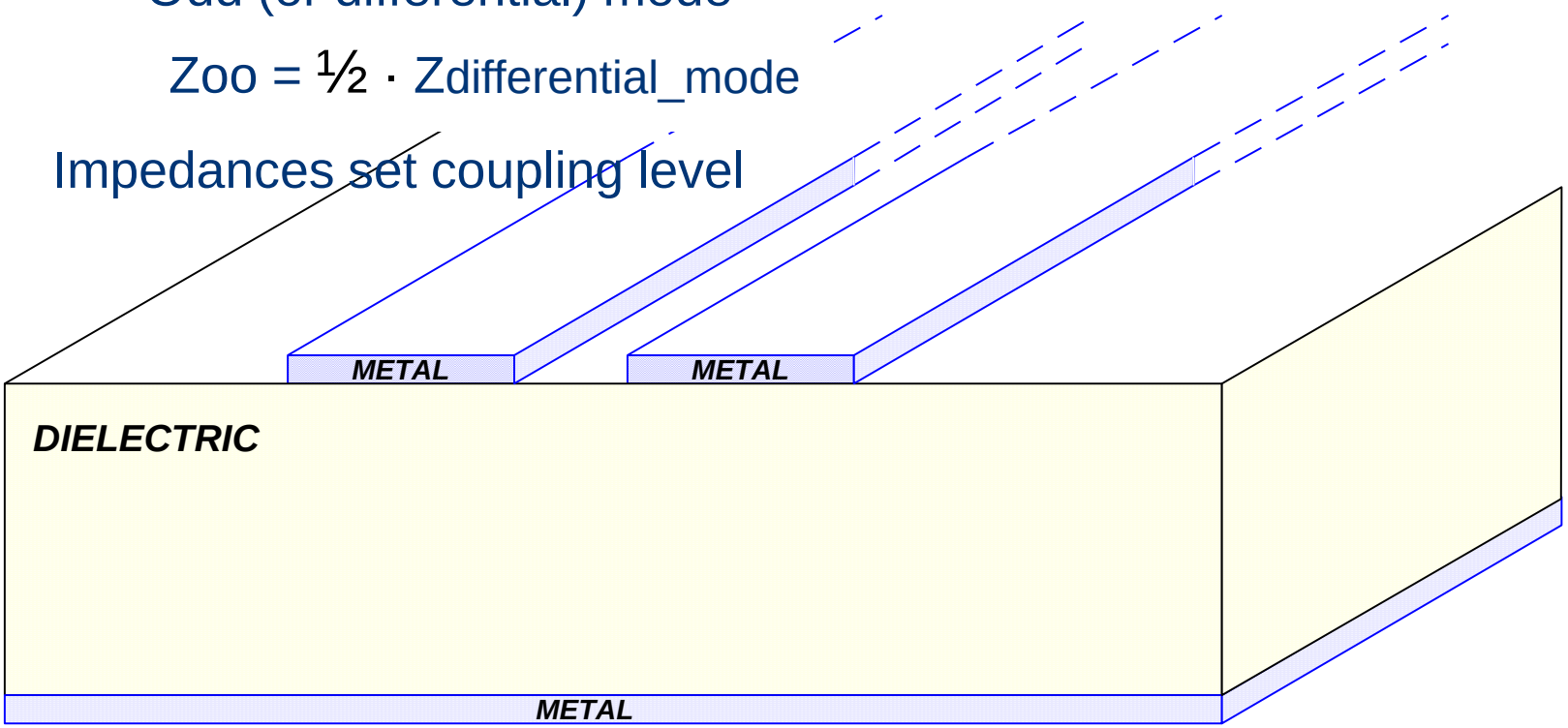
- Two transmission-line modes:
  - Even (or common) mode

    Zoe = 2 · Zcommon_mode

  - Odd (or differential) mode

    Zoo = ½ · Zdifferential_mode

- Impedances set coupling level



COUPLING COEFFICIENT k

$$C_{dB} = -20\log(k)$$

$$k = 10^{\left(\frac{-C}{20}\right)}$$

$$k = \frac{\frac{Zoe}{Zoo} - 1}{\frac{Zoe}{Zoo} + 1}$$

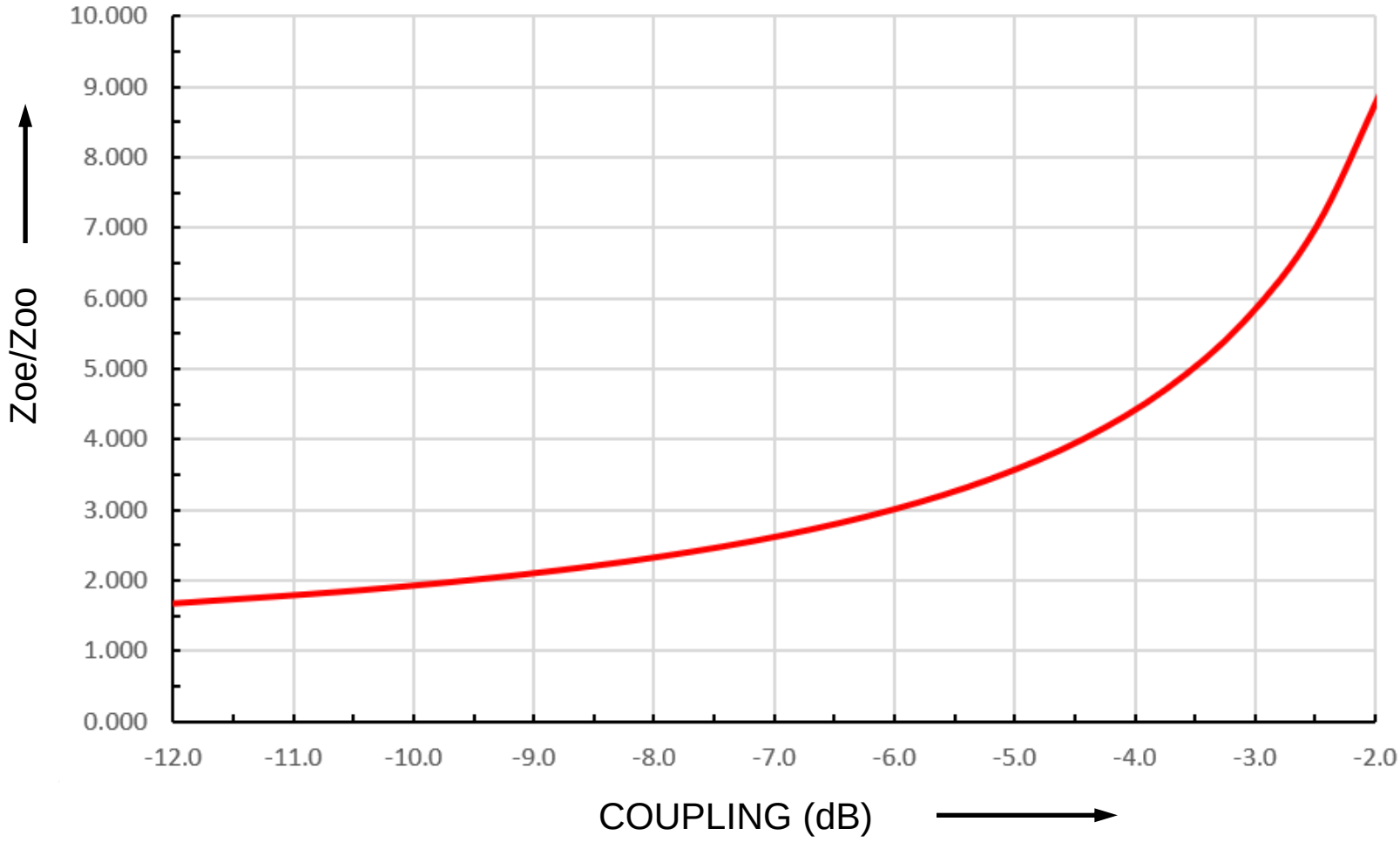
$$Zoe = \sqrt{\frac{1+k}{1-k}}$$

$$Zoo = \sqrt{\frac{1-k}{1+k}}$$

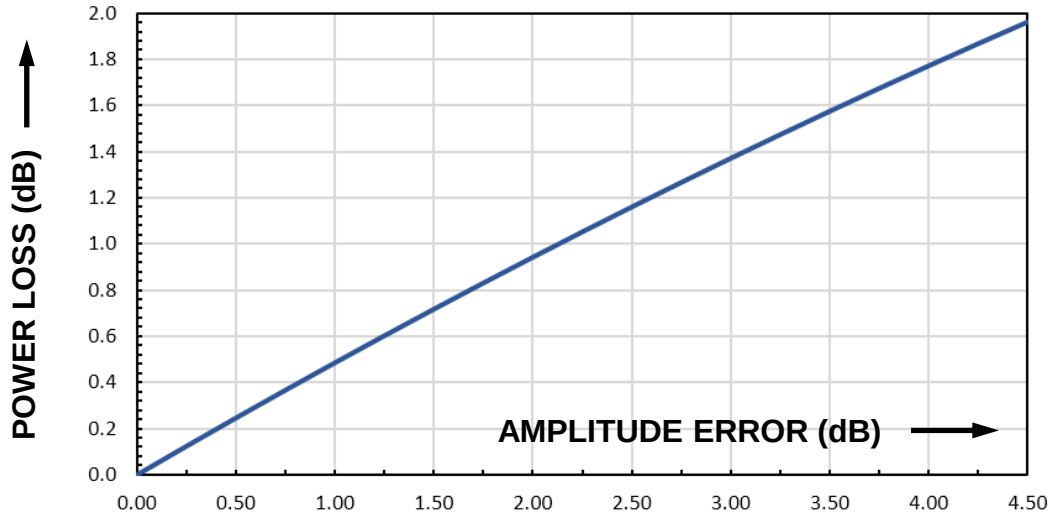
$$Z_o = \sqrt{Zoe\ Zoo}$$

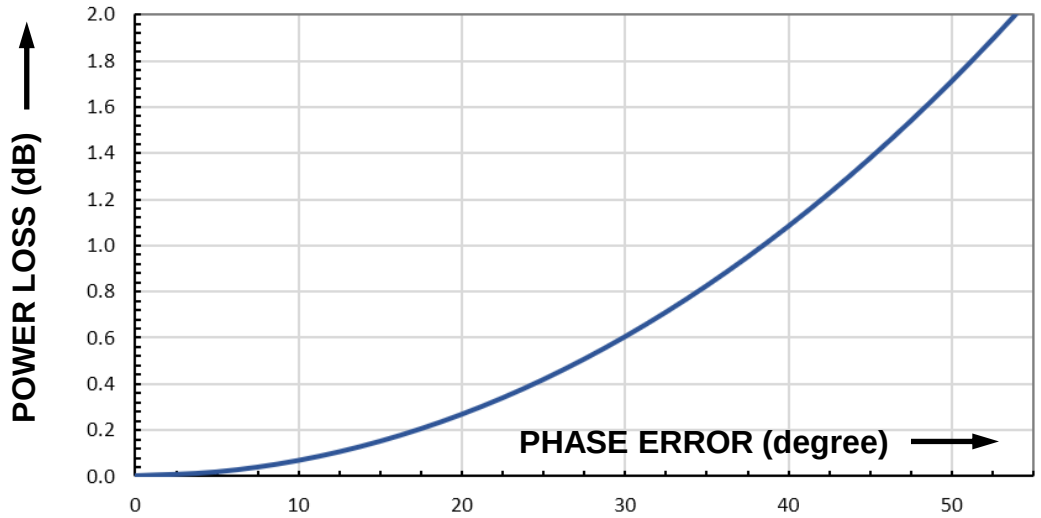
- 3 dB coupler: k = 0.707
- Slight over coupling improves BW
- 50 Ω 3 dB coupler impedances:
  Zoe = 120.7 Ω
  Zoo = 20.7 Ω

Zoe/Zoo vs COUPLING (dB)

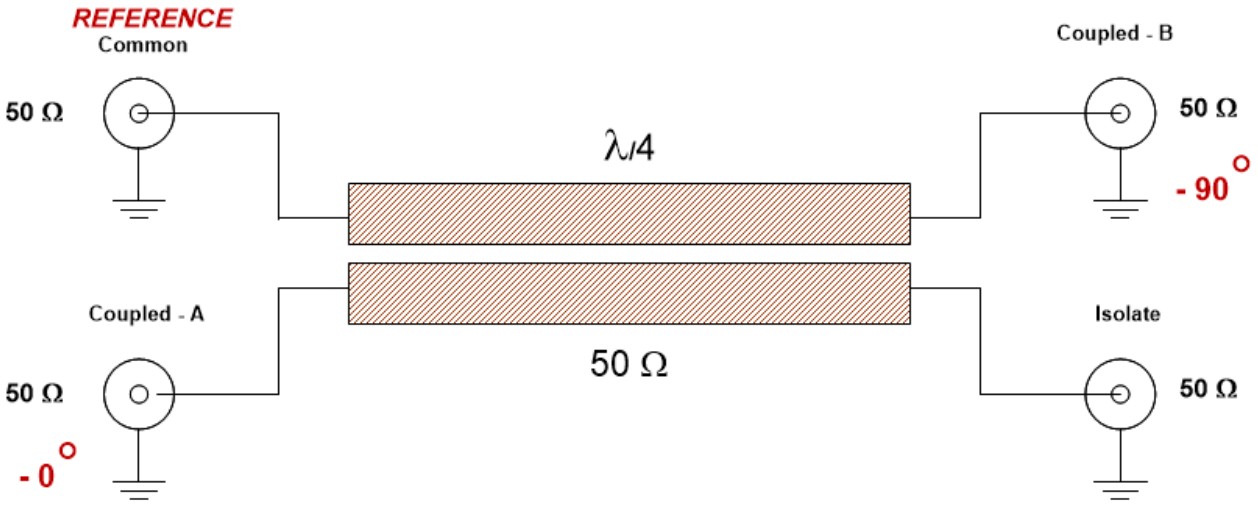


POWER COMBINING LOSS DUE TO ERROR



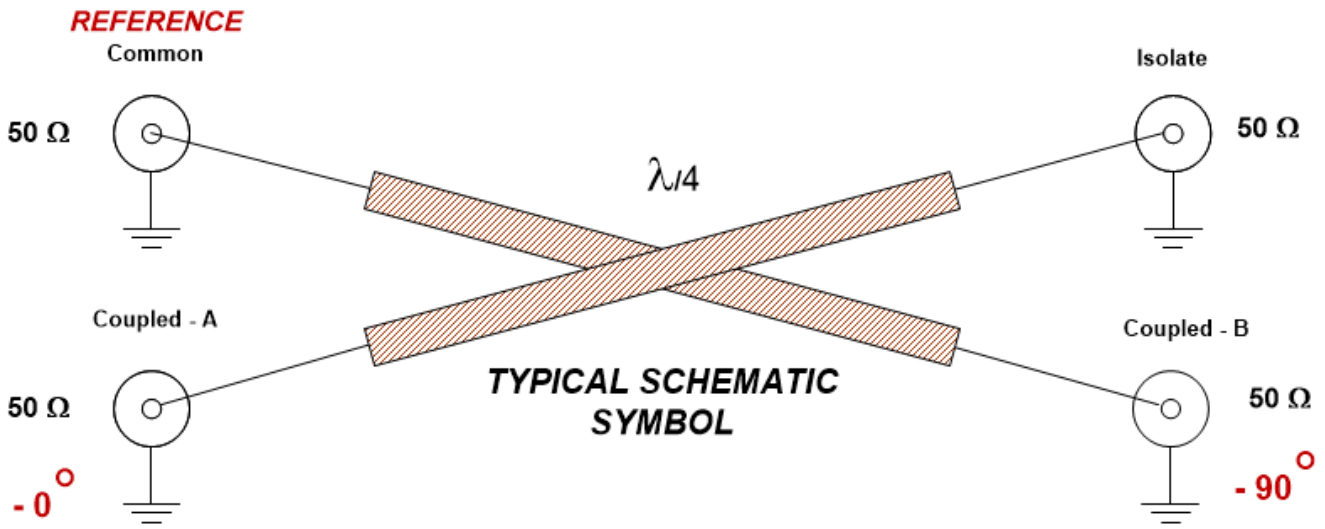


BASIC DIRECTIONAL COUPLER



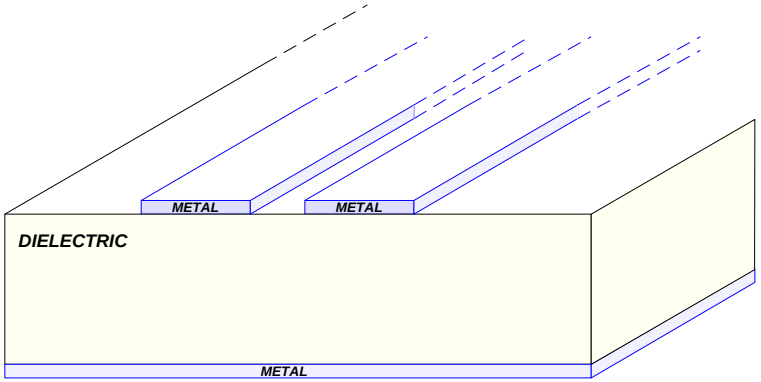
- Port phase relationships are independent of coupling level
- Coupled port (A) level is set by coupling
- Coupled port (B) level (the through line) receives the remainder of input signal that is not coupled to port (B)

FOLDED COUPLER SYMBOL

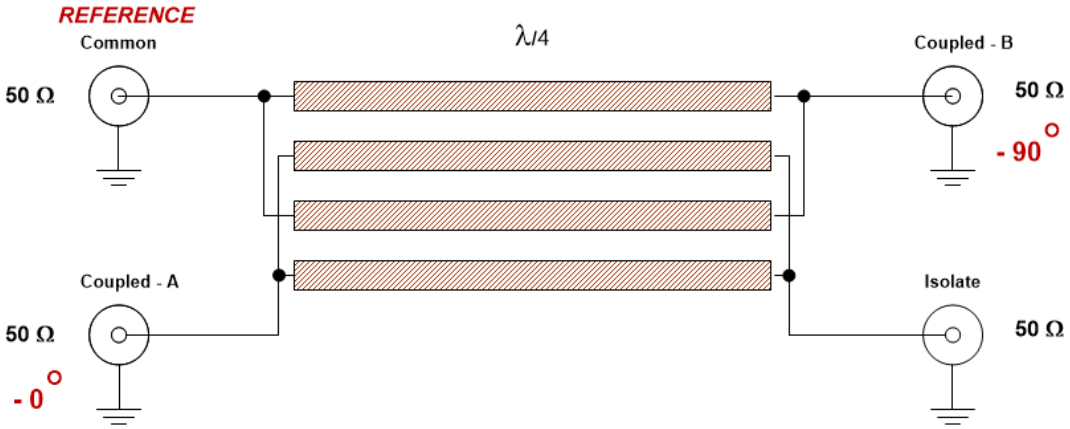


- Convenient schematic representation for 3 dB hybrids
- Both coupled ports are drawn on same side of coupler
- Often used schematically for any of the coupled line structures

LANGE COUPLER

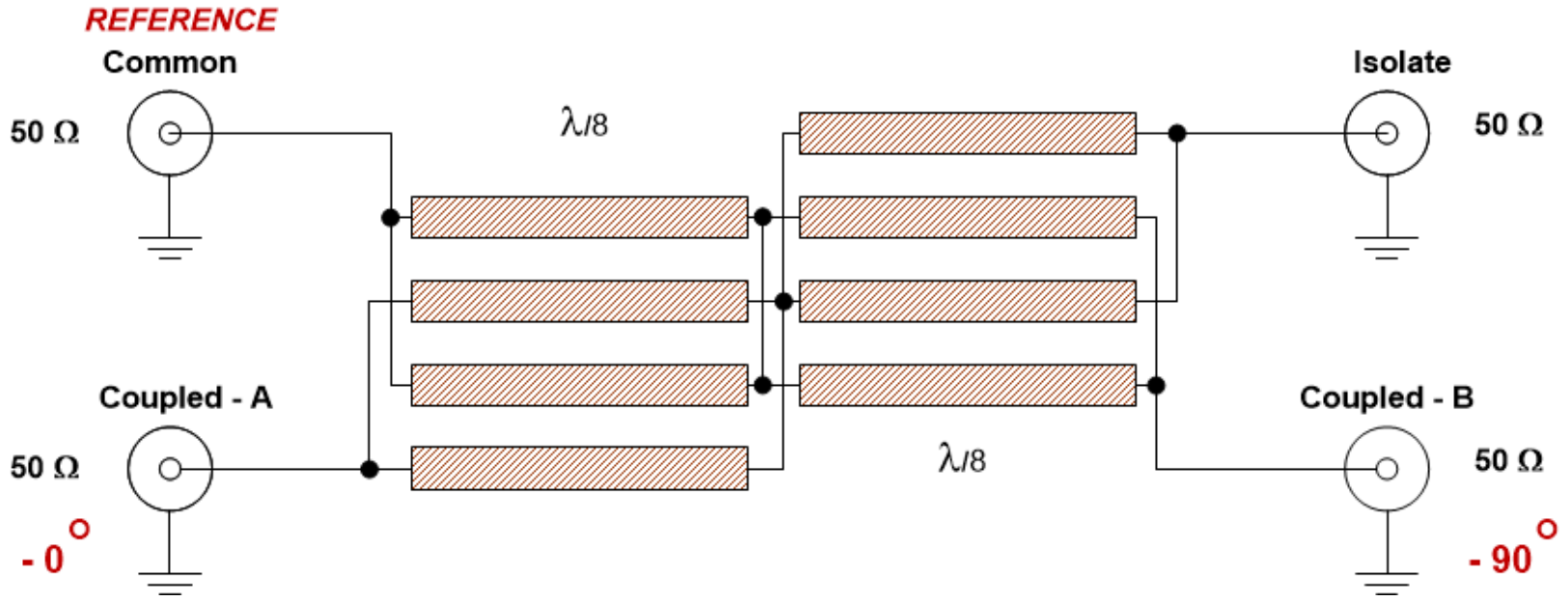


- Coupled microstrip couplers are practically limited by dimensions to around -10 dB coupling
- We need at least -3dB coupling



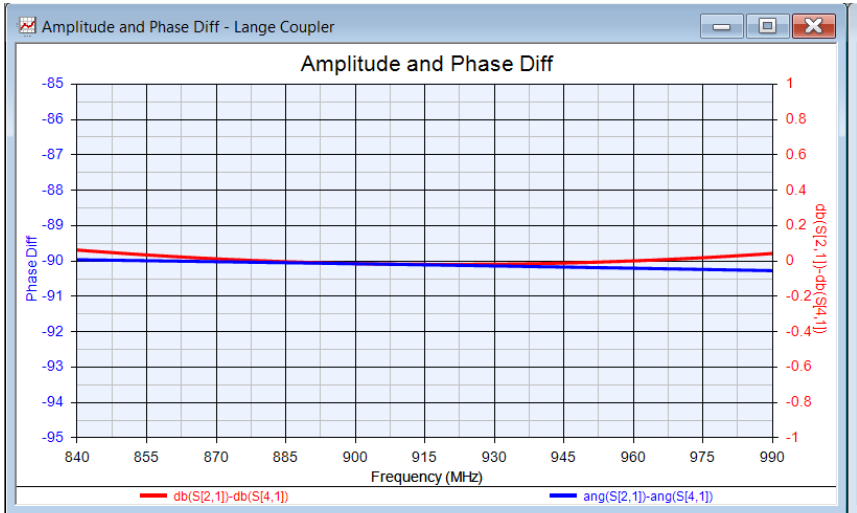
- If the lines are split and interdigitated, greater coupling can be achieved
- This is the basic Lange coupler

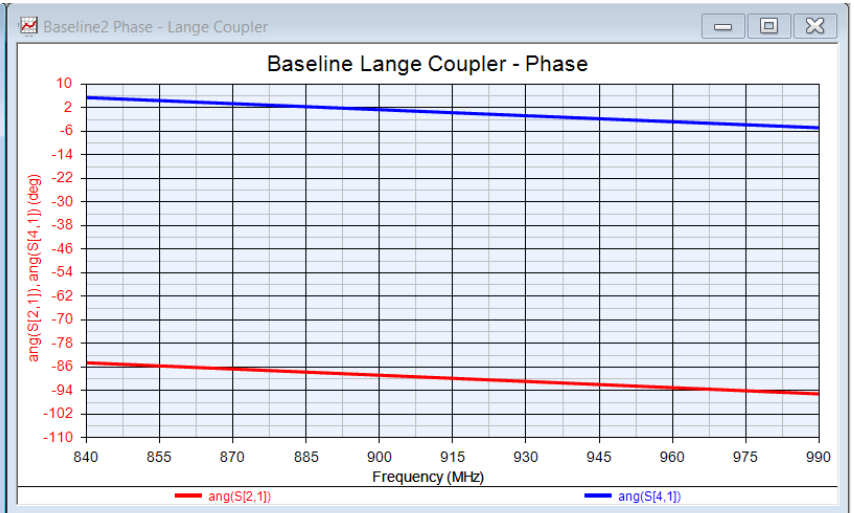
FOLDED LANGE COUPLER

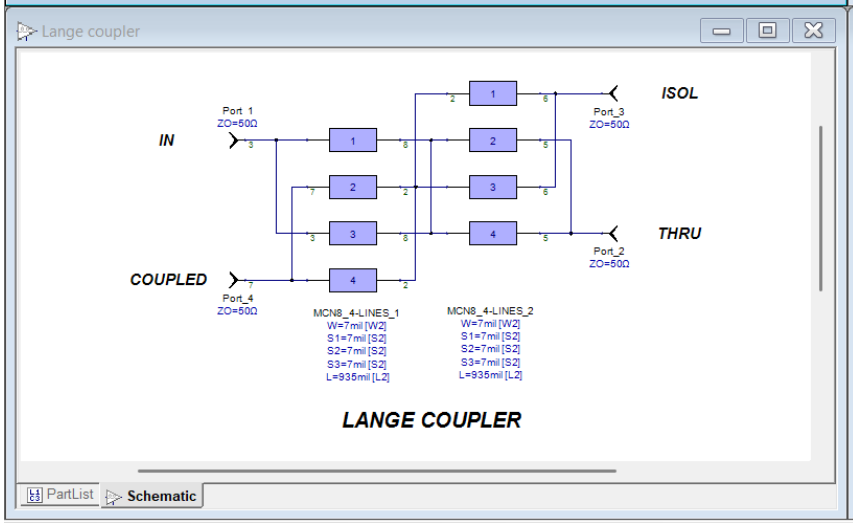


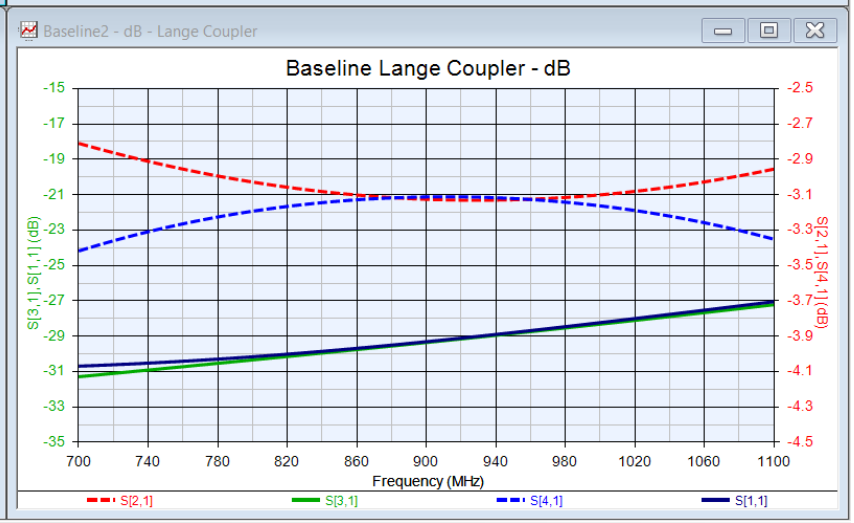
- Folded Lange coupler has both coupled ports on the same side
- This is the most commonly used form

FOLDED LANGE COUPLER - RESPONSE

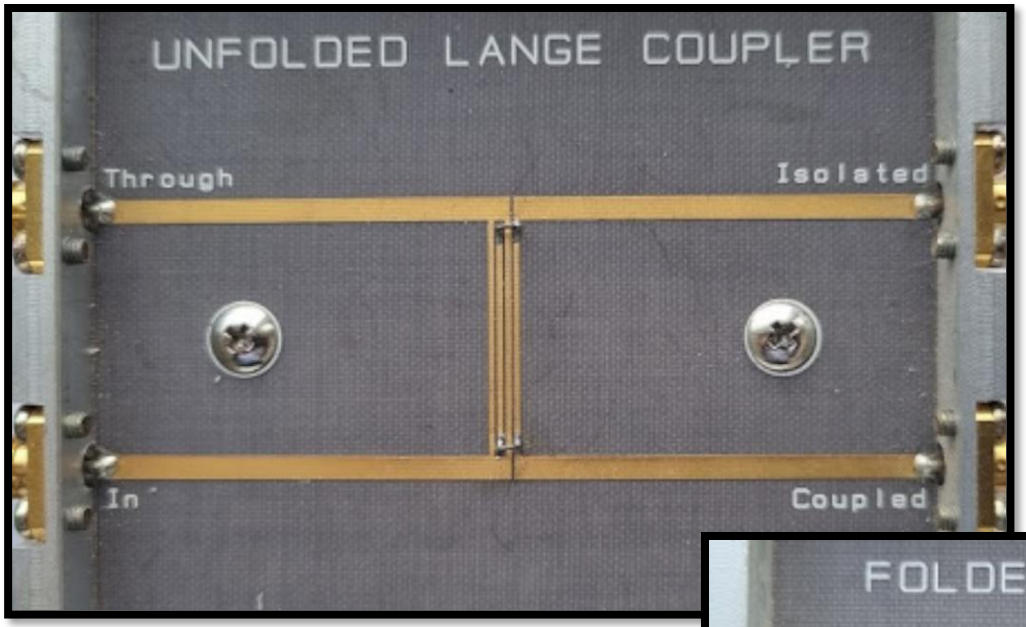


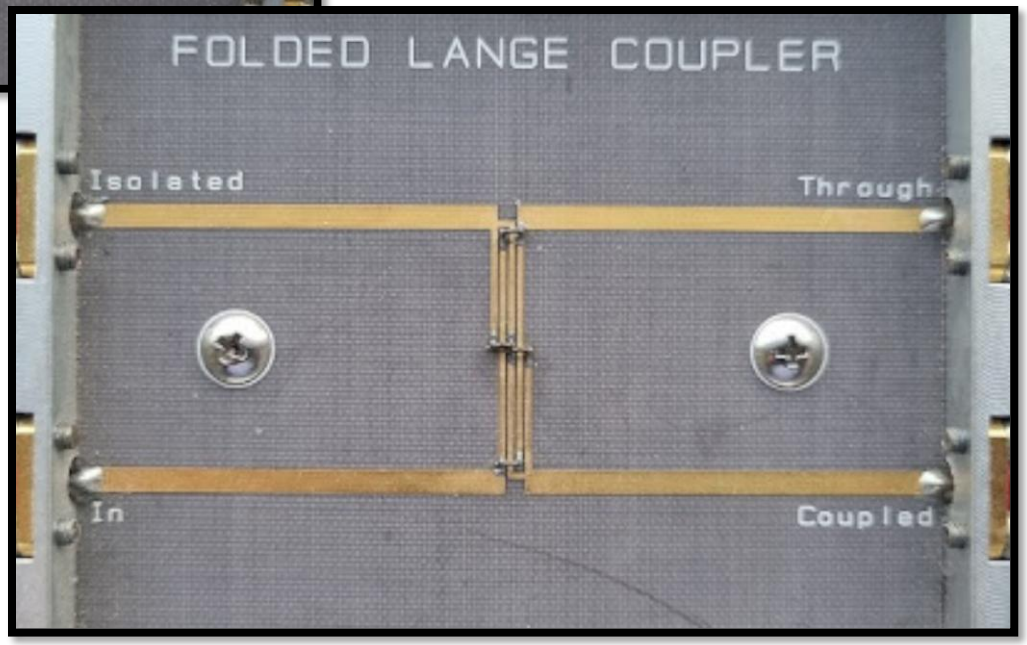




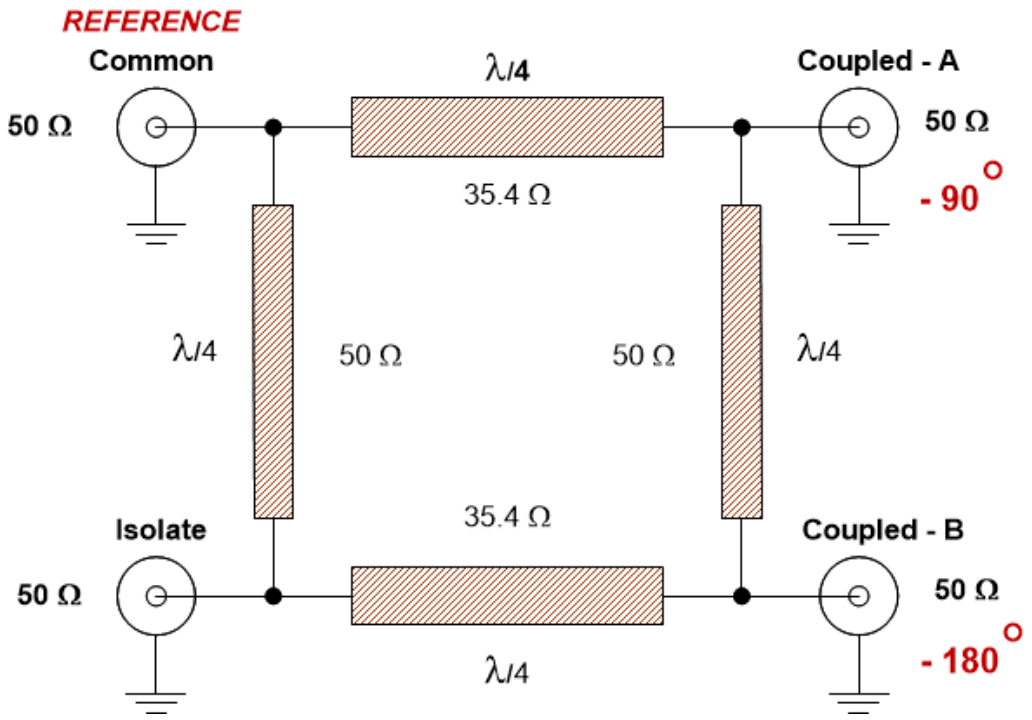


LANGE COUPLER PHOTOS



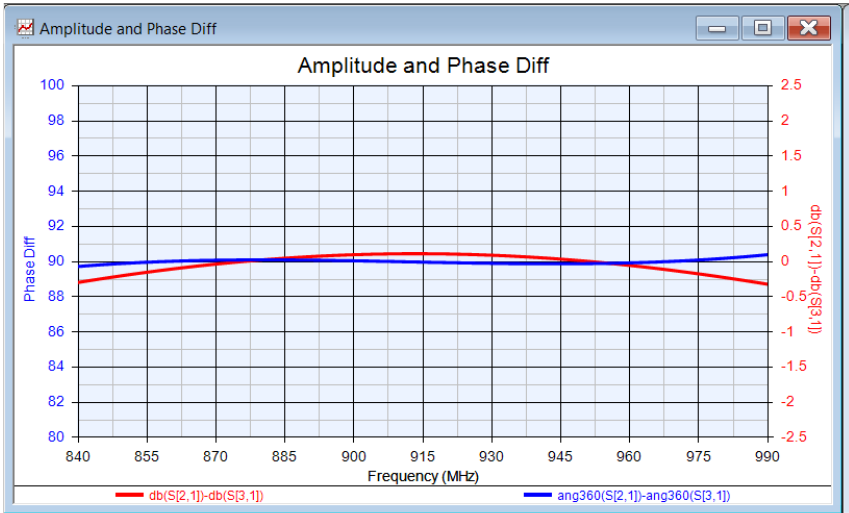


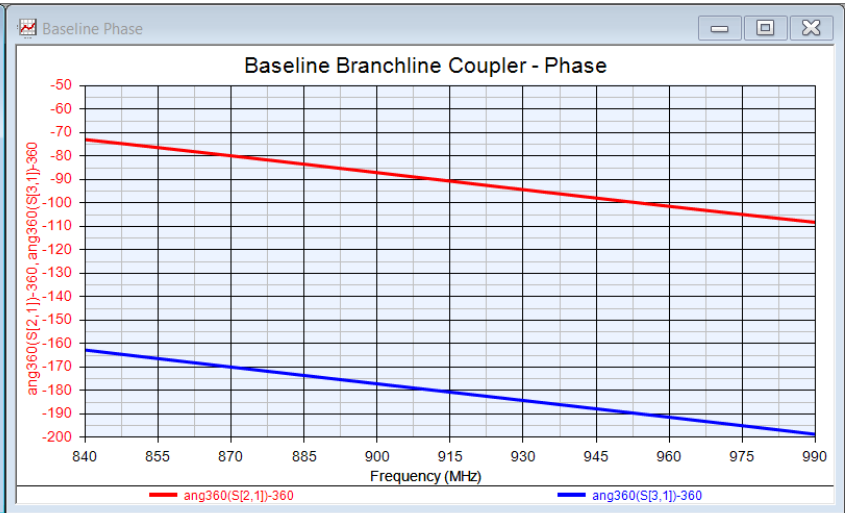
BRANCHLINE HYBRID

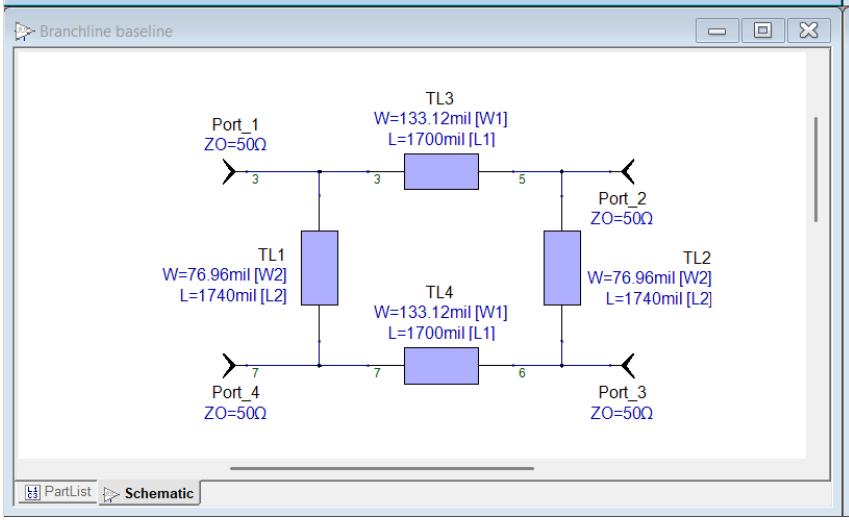


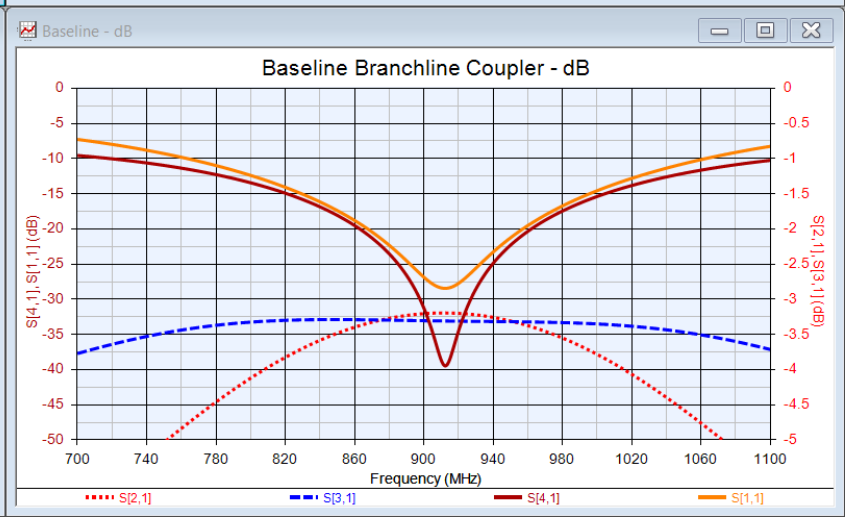
- The branchline hybrid does not use coupled lines
- Amplitude match of coupled ports isn't as good as the Lange coupler
- Power handling of a branchline hybrid is better

BRANCHLINE HYBRID - RESPONSE

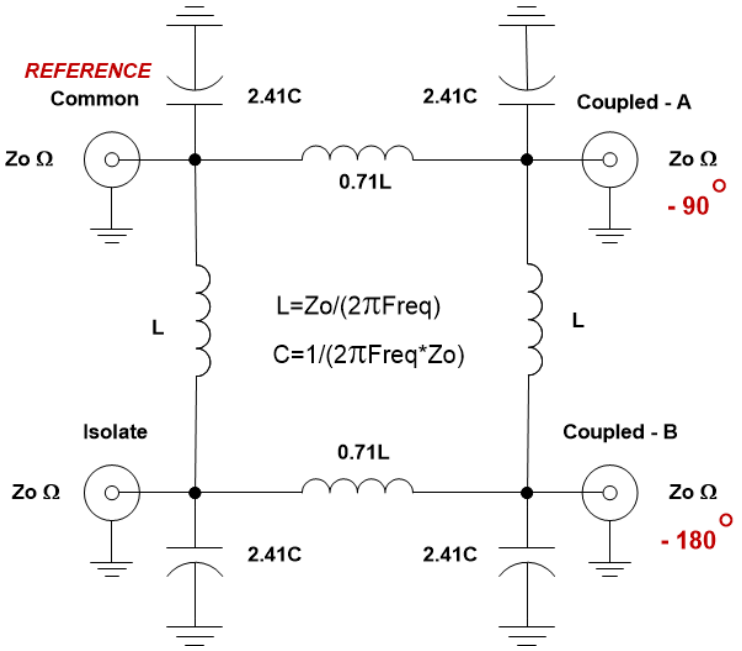




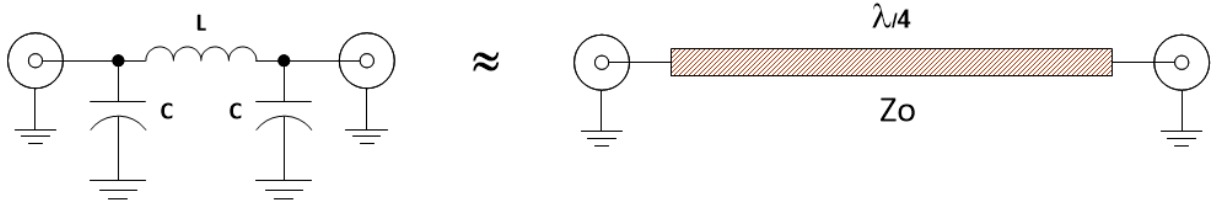




LUMPED BRANCHLINE HYBRID

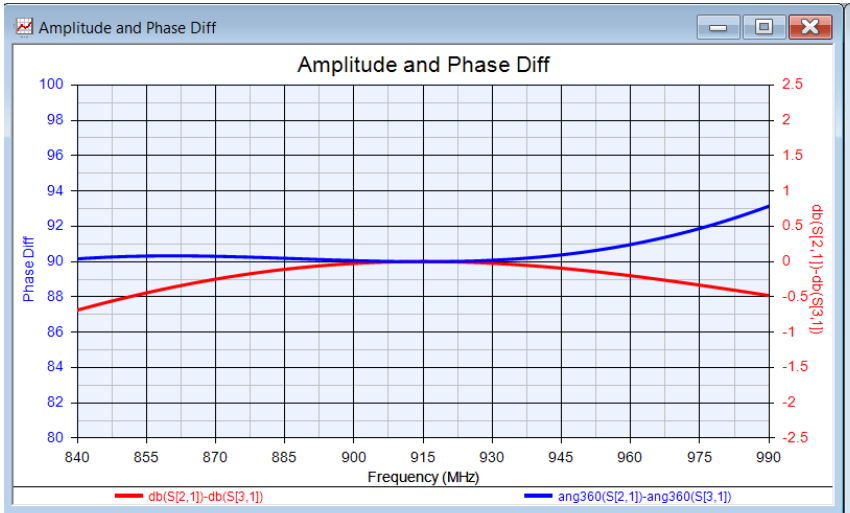


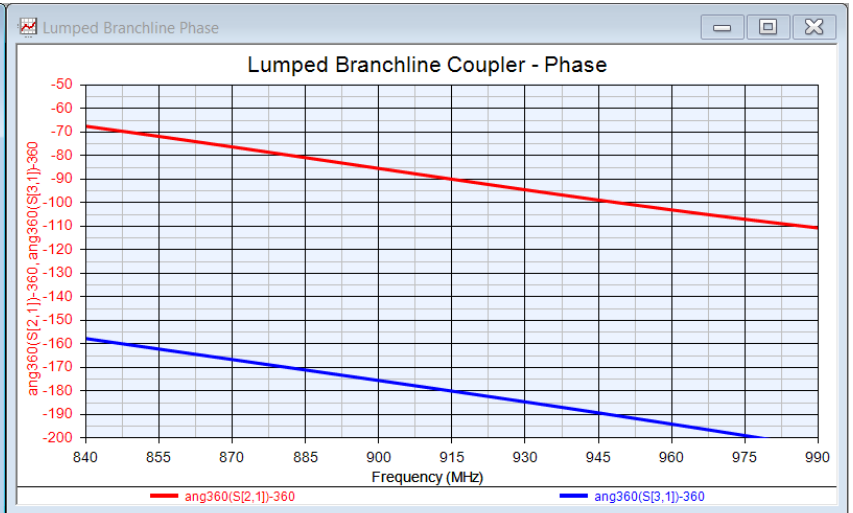
- A lumped branchline hybrid uses an LC approximation of the branchline quarter-wave lines:

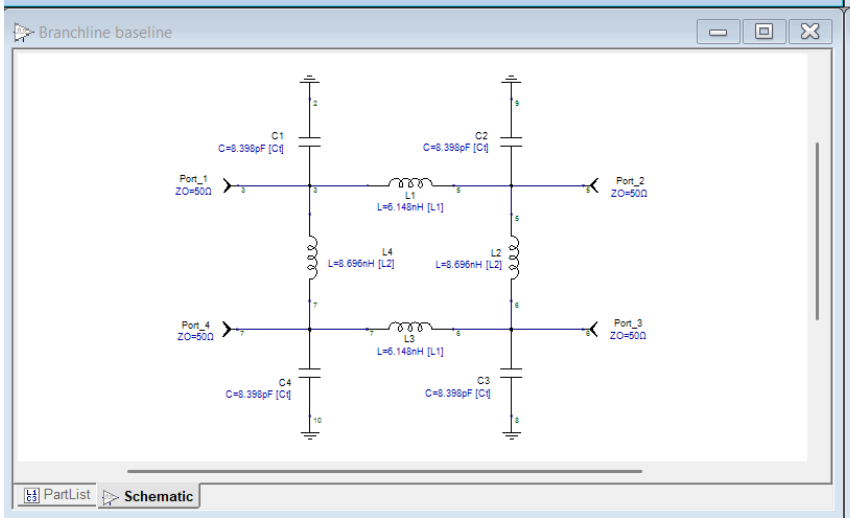


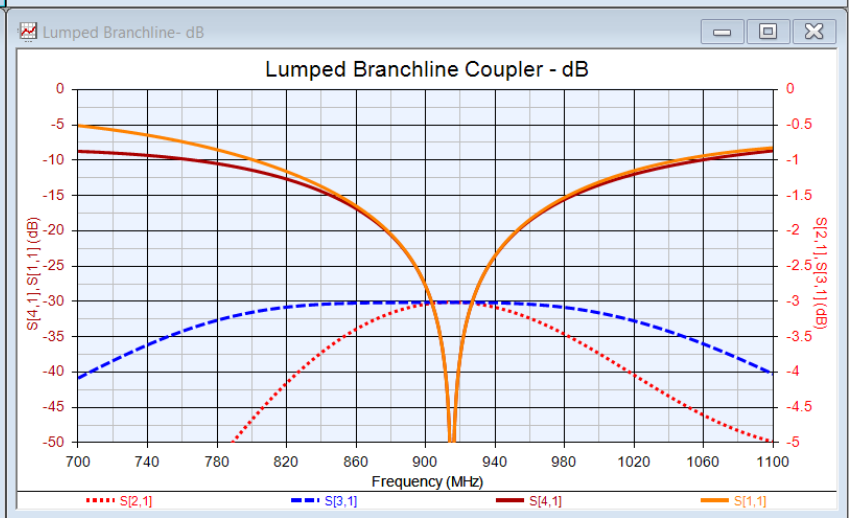
L=Zo/(2πFreq)
C=1/(2πFreq*Zo)

LUMPED BRANCHLINE HYBRID - RESPONSE

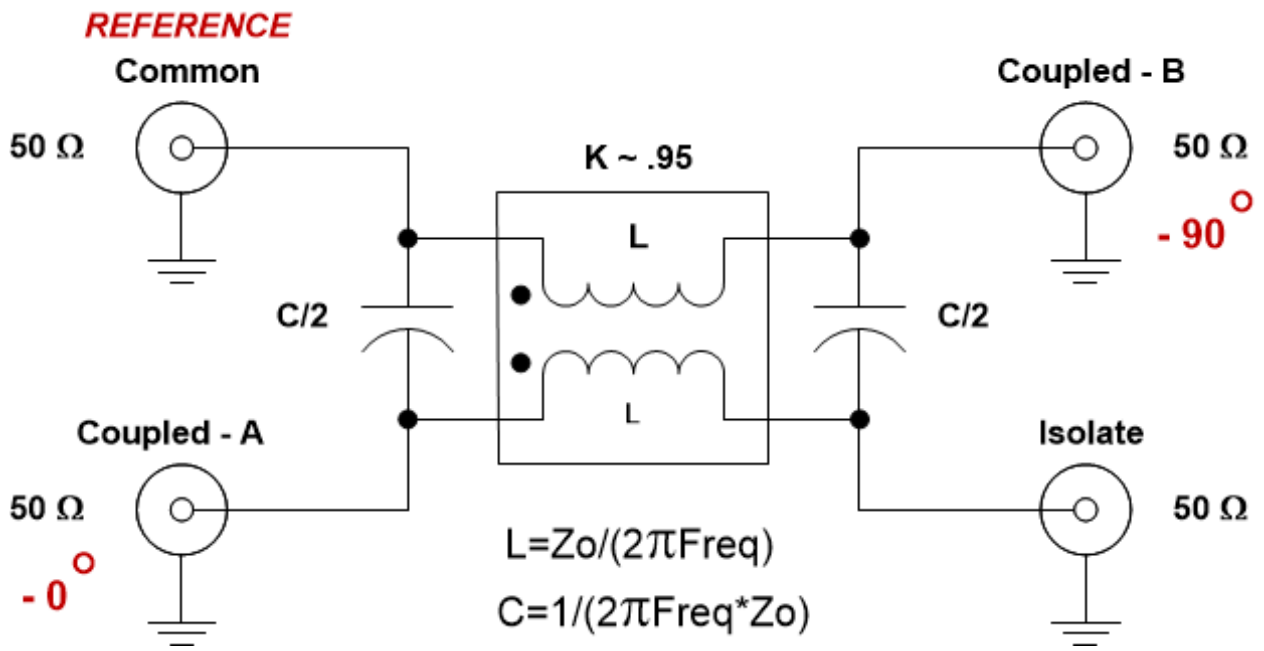






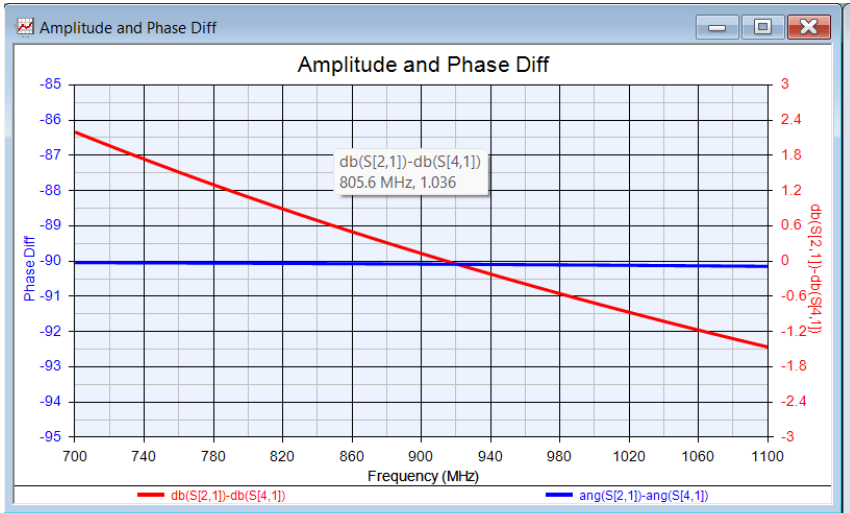


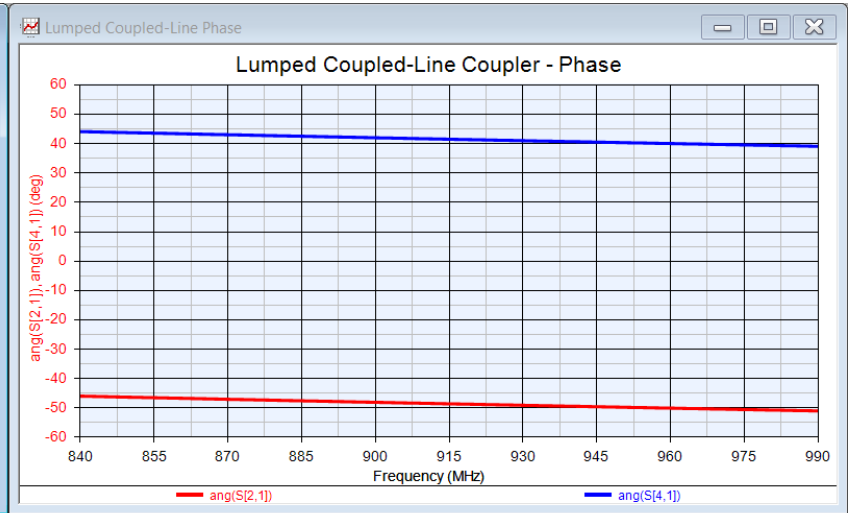
LUMPED COUPLED-LINE HYBRID

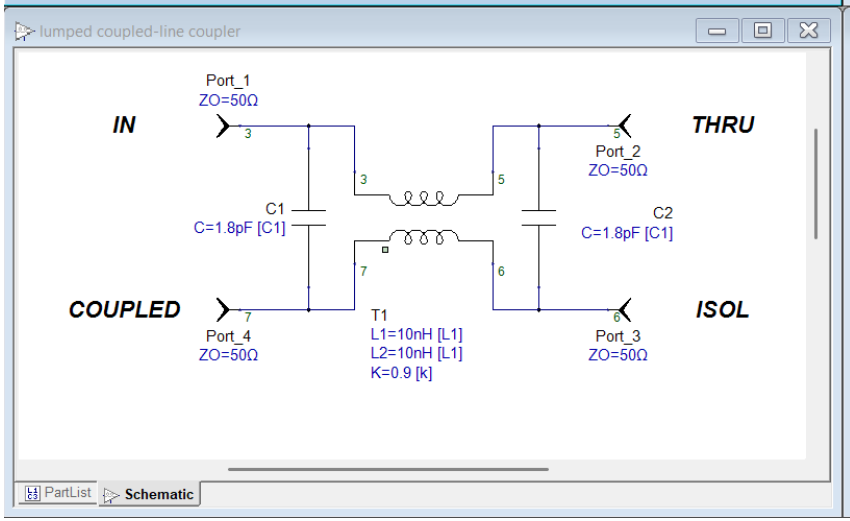


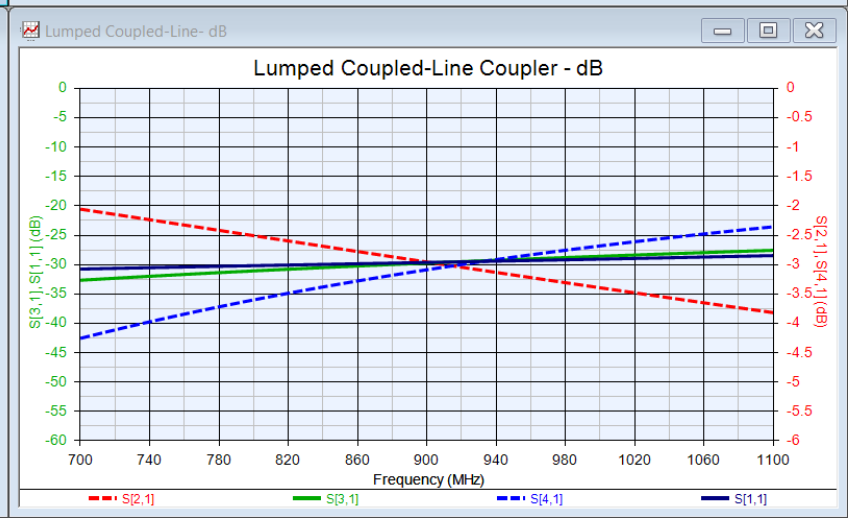
- A lumped coupled-line hybrid uses a tightly coupled pair of inductors
- Amplitude response is very narrow-band

LUMPED COUPLED-LINE HYBRID - RESPONSE

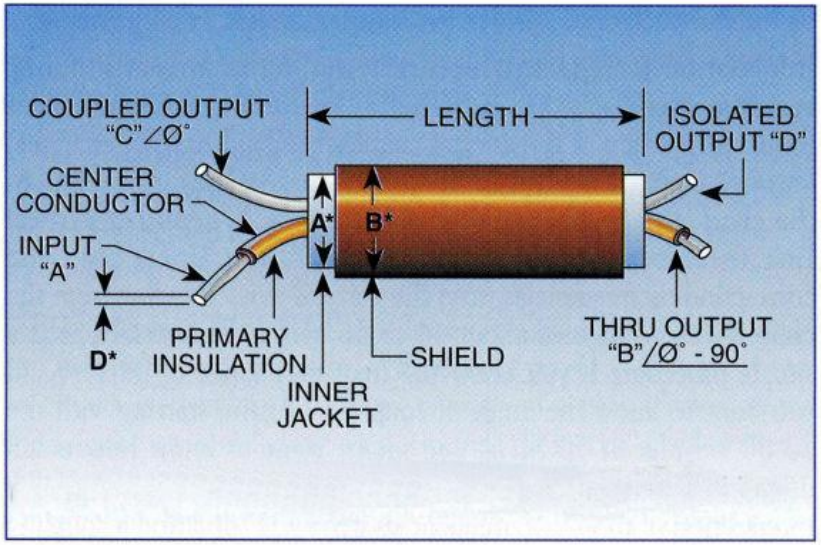


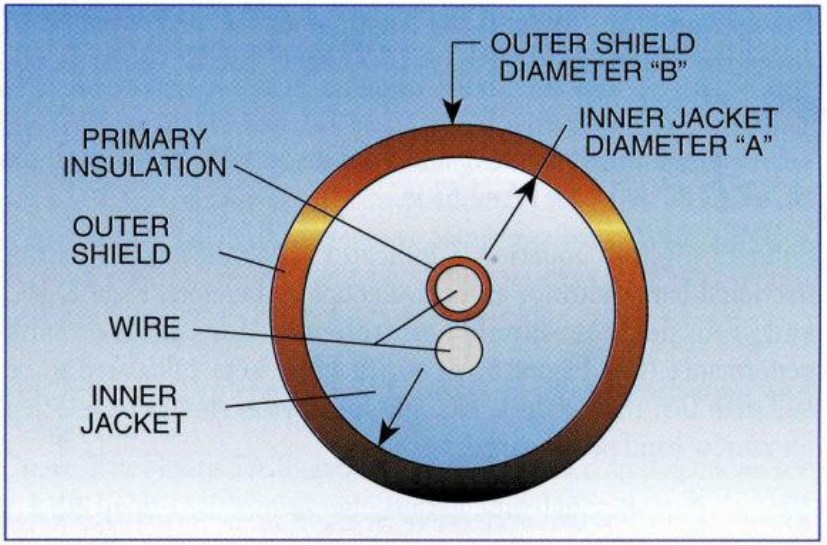






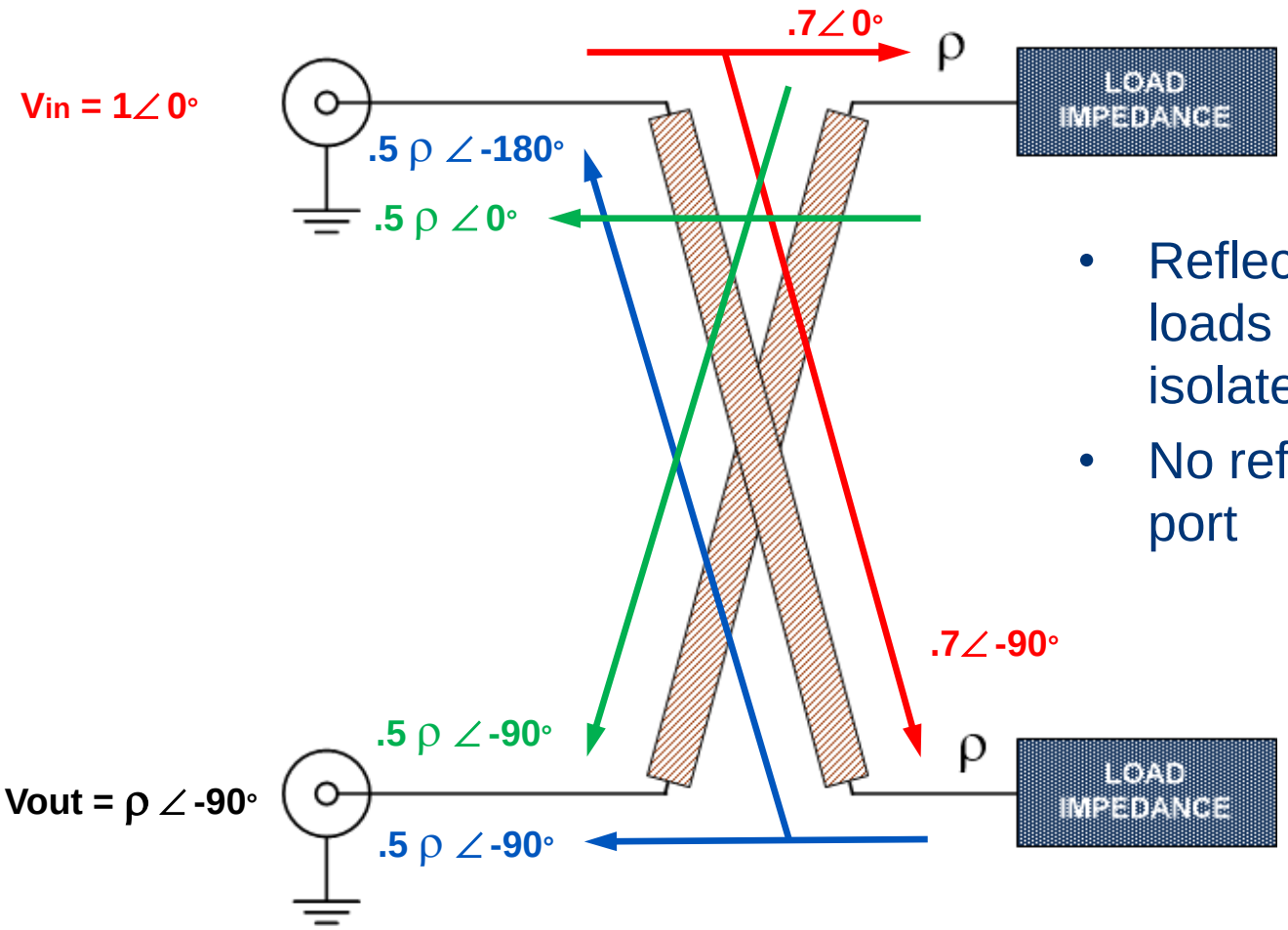
WIRELINE COUPLED LINE HYBRIDS





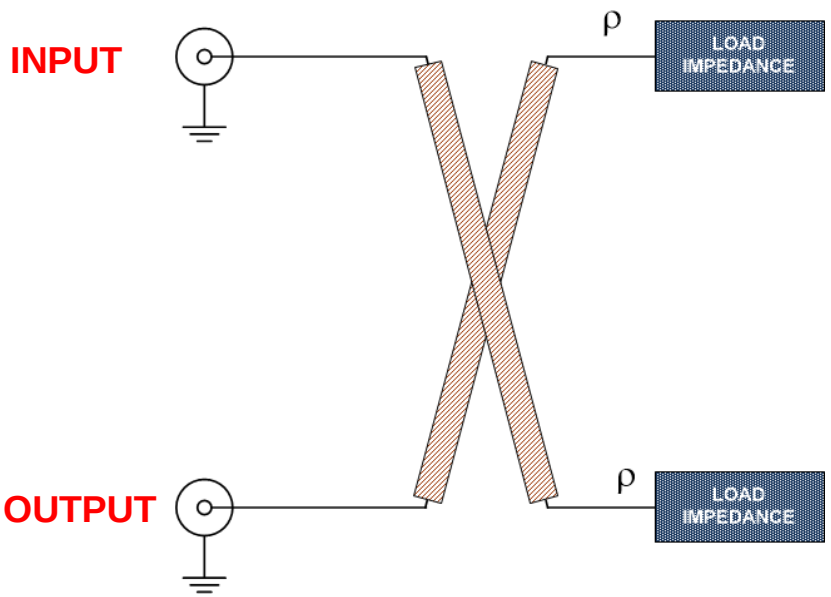
- A shielded pair of lines can provide a directional coupler
- 3 dB couplers of this form were first sold by Sage Labs (now API)

SPECIAL REFLECTION CHARACTERISTICS



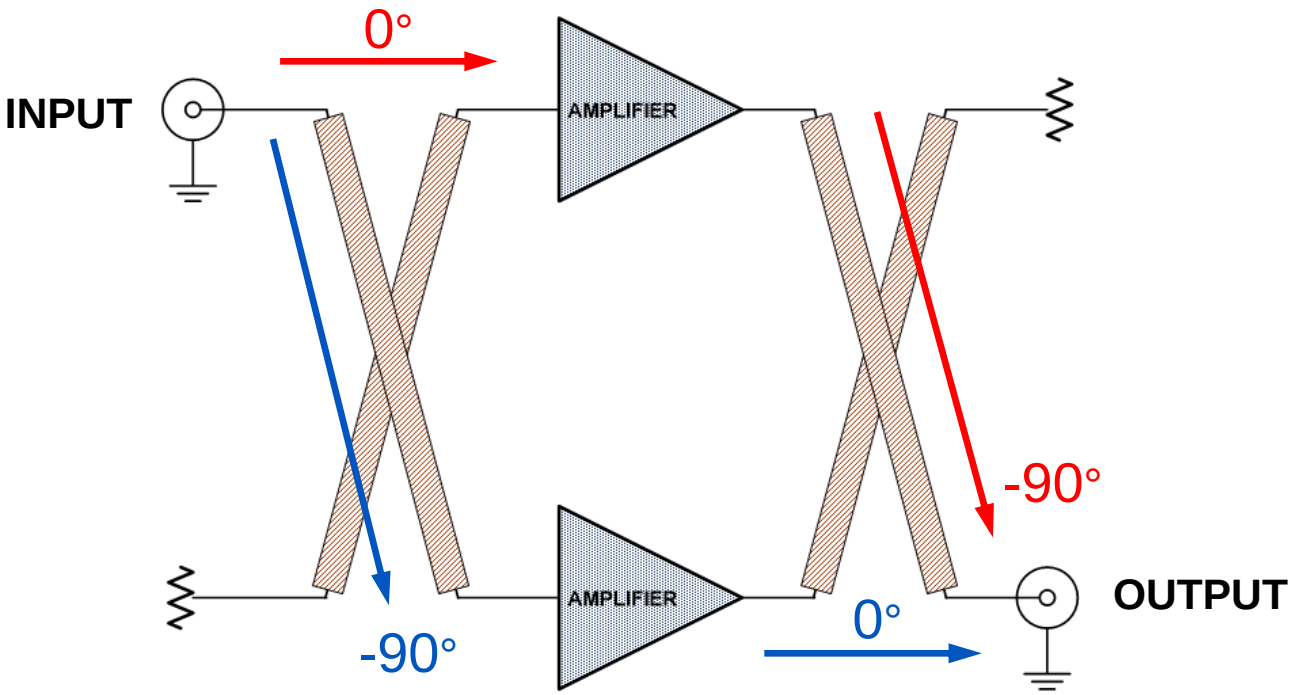
- Reflection from equal loads combine to the isolate port (Vout)
- No reflection to input port

APPLICATIONS – DIODE CIRCUITS



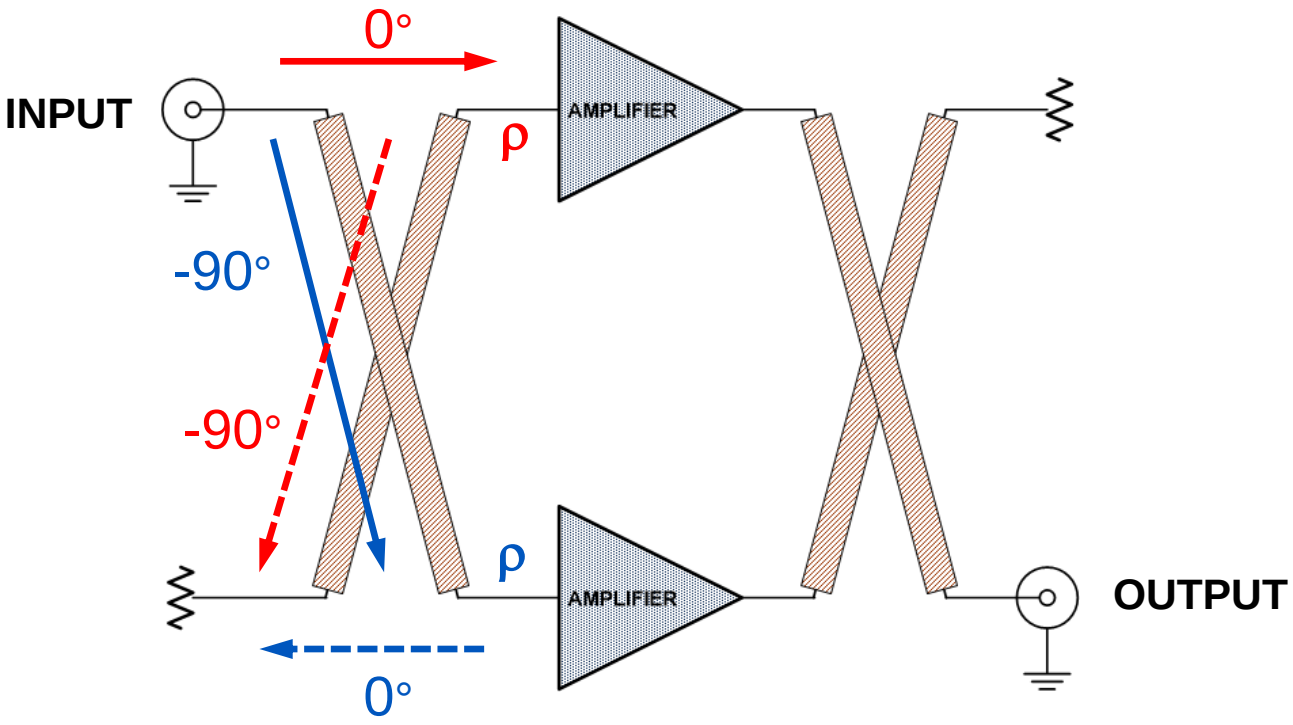
- Amplifier from negative resistance diodes: Impatt, Gunn or Tunnel
- Variable phase shifter from varactor diodes
- Variable attenuator from PIN diodes

APPLICATIONS – AMPLIFIER COMBINING



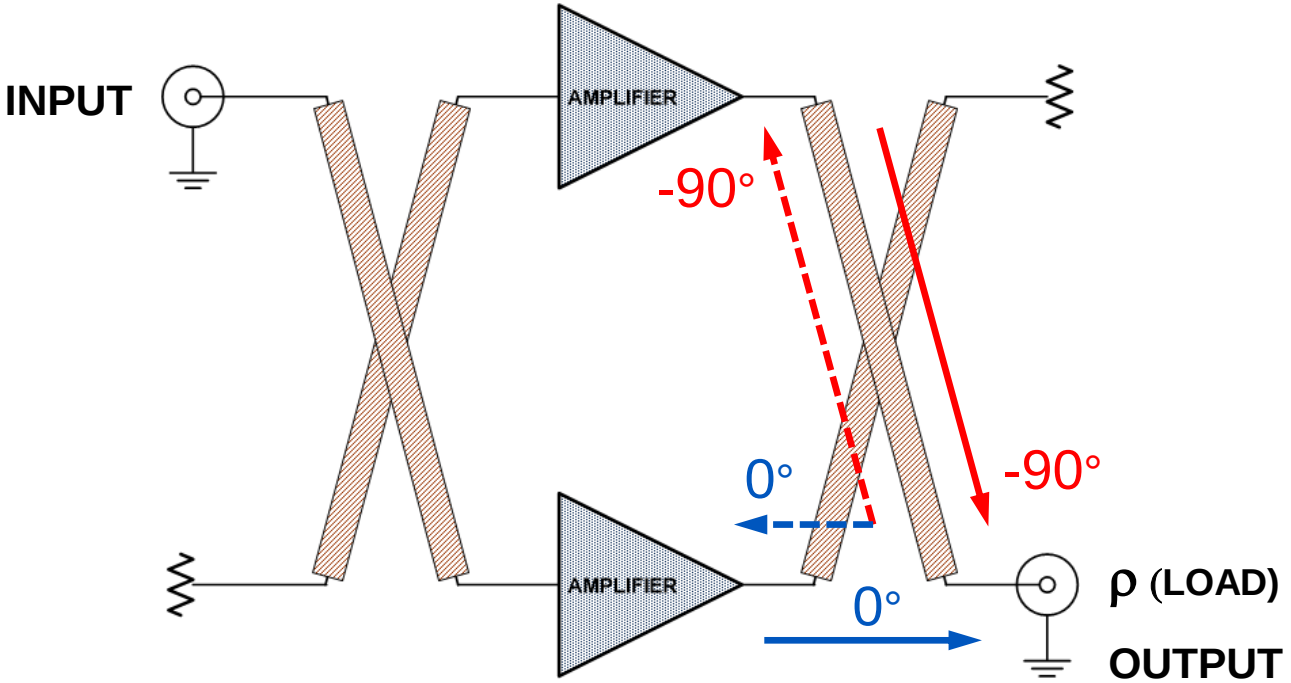
❶ The total phase shift through hybrids is -90° for each amplifier path to the output port. Both amplifier signals arrive in-phase at the output port.

APPLICATIONS – AMPLIFIER COMBINING



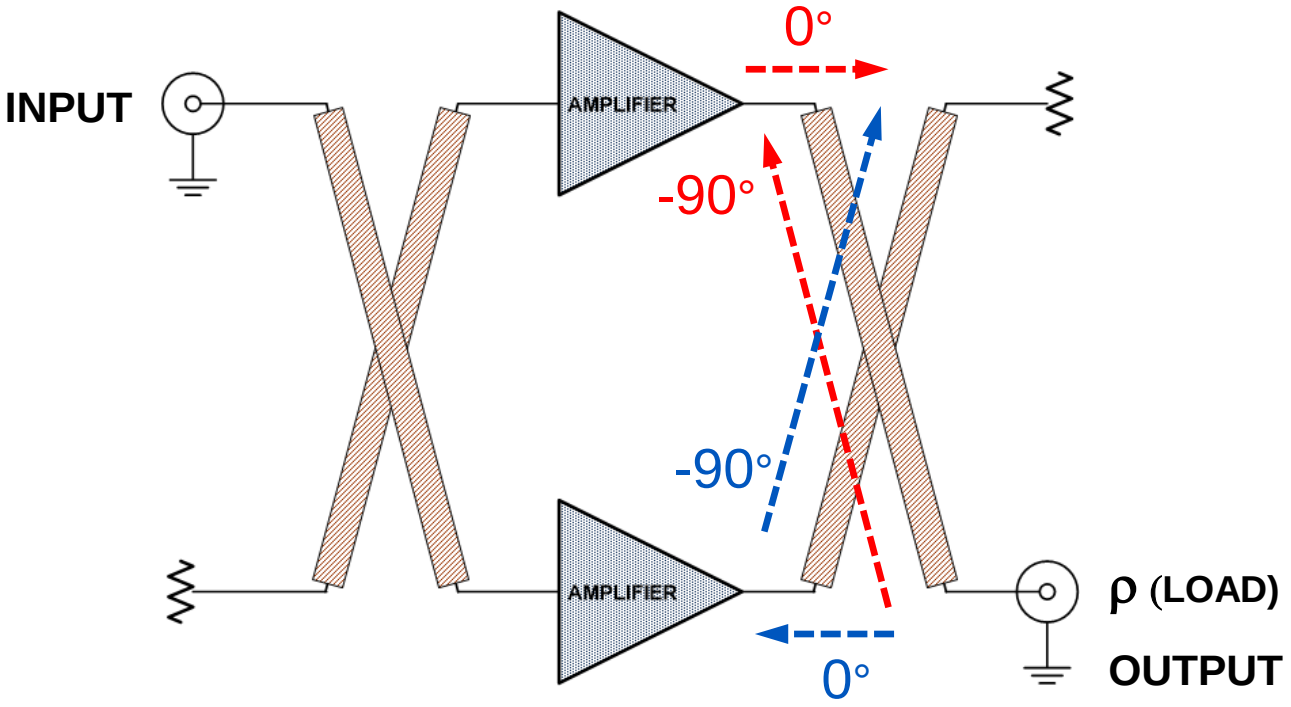
❷ Input from each amplifier is sent to the isolate termination. The path phase shift for each amplifier to the isolate termination is: ∠ρ - 90° . Input VSWR of the pair is 1:1.

APPLICATIONS – AMPLIFIER COMBINING



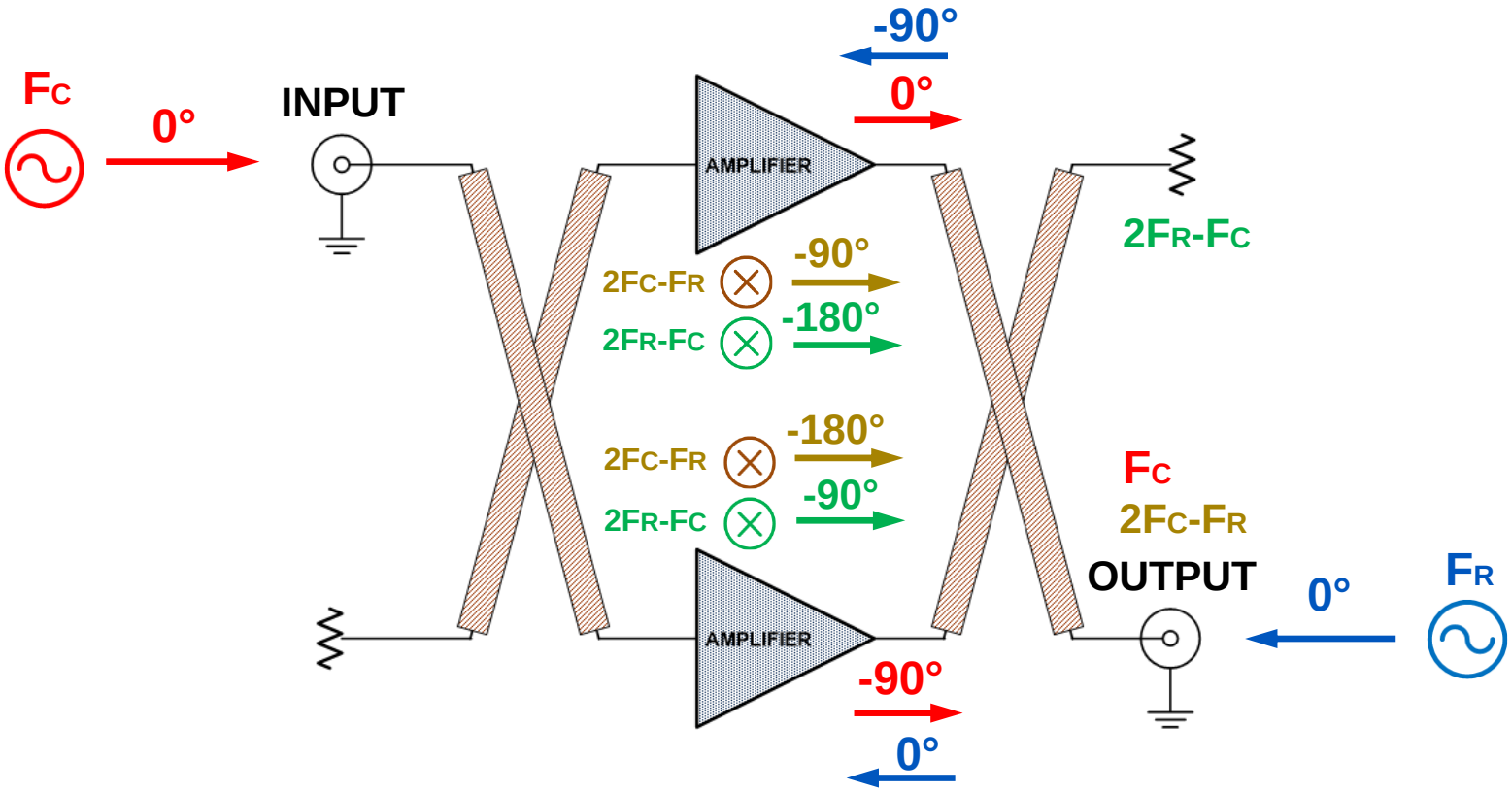
❸ Load mismatch is applied differently. Upper amplifier sees the load reflection shifted by -180° more than the lower amplifier. This desensitizes the pair. If one amplifier is more heavily loaded, the other is more lightly loaded. The total supply current is more constant. Note: Both amplifiers do see a mismatched load.

APPLICATIONS – AMPLIFIER COMBINING



❹ Power amplifier output match is for power not reflection; so, a single amplifier operating into a mismatch experiences multiple reflections due to mismatched source and load. This problem is mitigated in quad-combined amplifiers. Any reflected signal from the amplifier output is combined at the isolate termination.

APPLICATIONS – AMPLIFIER COMBINING



❺ Reverse IMD: $2F_R-F_C$ is sent to the output isolate termination. Reverse IMD: $2F_C-F_R$ is sent to the output Port.

Conclusion: some reverse IMD is suppressed.

APPLICATIONS – AMPLIFIER COMBINING

- Both amplifier total phase shift is through hybrids is -90°.
- Input and output reflection from each amplifier is sent to the isolate termination: VSWR of the pair is 1:1.
- Load mismatch is applied differently (by 180°) to the amplifiers. This desensitizes the pair.
- Multiple reflections due to amplifier output mismatch are terminated in the isolate load.
- Reverse IMD performance is improved.

SUMMARY

- Quadrature hybrids offer many advantages
- They are realized with -3 dB directional couplers or with branch-line structures.
- Lange couplers provides superior performance in microstrip media
- Applications include one port devices circuits (negative resistance amplifiers, phase shifters, and attenuators) and two port amplifiers.

Questo E' Tutto