

# RADITEK

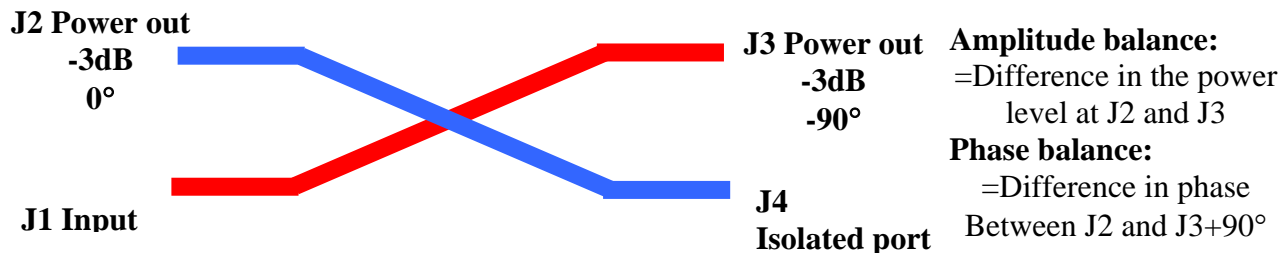
## Quadrature Hybrids

**Some definitions:**

**$Z_{oo}$  or Odd Mode Impedance** is defined as the Characteristic Impedance of one line (to ground), when equal currents are flowing in the two lines.

**$Z_{oe}$  or Even Mode Impedance** is defined as the Characteristic Impedance of one line (to ground), when equal and opposite currents are flowing in the two lines.

A number of strip-line components utilize the natural RF field coupling existing between parallel conductors. The characteristics of these coupled lines can be analyzed in terms of Odd ( $Z_{oo}$ ) and Even ( $Z_{oe}$ ) mode Impedance's. The following describes the properties and applications of the backward wave coupler, also known as 3dB Directional or 3dB/Quadrature hybrid couplers.

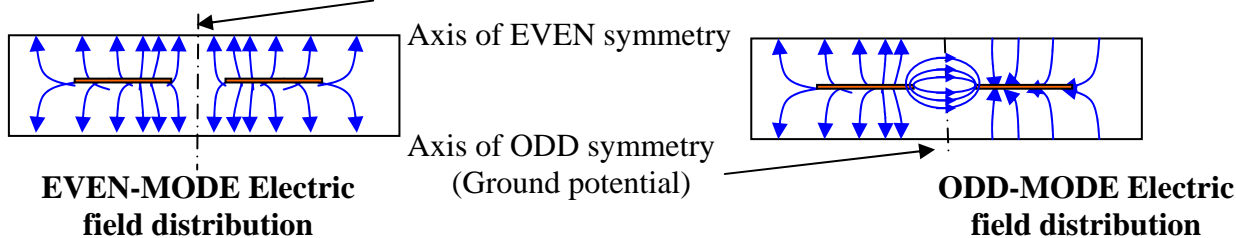


The hybrid schematic above is shown as a splitter.  
As a combiner input on J2 and J3 will be combined at port J1.

A quadrature hybrid is a special coupler, used in power amplifiers, for example, to split and combine RF power; so multiple higher power devices can be combined in the amplifier, to handle more RF power. A signal entering in one port (J1) will emerge at the opposite two ports (J2 and J4), but at 50% or 3 dB down from the input power level. Several levels of hybrids can be combined to realize a "tree structure" for more complex (i.e. more ports) splitter/combiner configurations for combining many devices.

The measure of a top performing coupler includes:

Lowest insertion loss, best (i.e. closest) Amplitude and Phase balance, and best (highest) Directivity or Isolation.

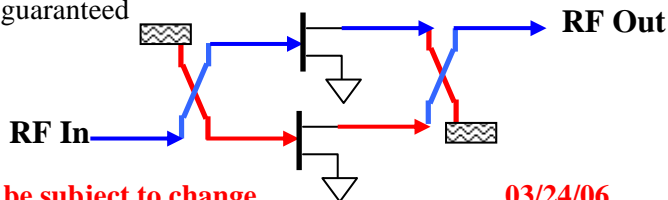


If the amplitude balance is poor, this probably means that there is more power coming out of one port than the other. This means one of the two or more devices being driven from the Hybrid will be driven at a lower power level, and the amplifier power and efficiency will degrade, the worse the in-balance, the worse the efficiency and output power.

Of the coupler design itself, the even mode impedance is typically designed to critical couple or slightly over couple at the mid frequency band. It can be shown that amplitude imbalance can usually be improved by over coupling at band center.

The phase balance can be better than 1° for the same batch of couplers, but due to small tolerance, design and manufacturing processes, up to 2° or 3° phase variations are guaranteed

The hybrid is mainly used as shown. The P1dB of single FET, will be increased by 3dB (theoretically), by combining 2 FETs.



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## Quadrature Hybrids *Continued*

### Some coupler terms and definitions:

**Insertion loss:** Power loss in excess of the coupling loss (due to dielectric, reflection and conductor losses).

In theory, there is perfect match at the coupler ports and isolation is infinite (i.e. no power is coupled to the isolation port).

### Couplers

Directional couplers are used for sampling either frequency or power. The amount of power that “couples” from the main port to the coupled port is the Coupling factor, expressed in dB, typically. A 3dB coupler, however, can be used to split the incident power in half, similar to the 3 dB Hybrid. Depending on the power level being sampled, the coupled power is usually in the range of 10 to 30 dB, which is selected to minimize line loss, as well as couple the correct power. For example, a 6 dB coupler will cause a 1.25dB (25%) power loss in the main line, whereas a 20 dB coupler will only experience 0.044dB (1%). For 20dB and 30dB couplers, the normalized even mode impedance varies by only 3.5Ω. This is why the mean coupling tolerances with high coupling values are relatively loose.

Directivity is usually specified for couplers instead of Isolation. It is a “quality” measure of how well the coupled port is unaffected by mismatches on the main port. The higher the Directivity, the better the coupler performance when mismatched. A coupler with 20 dB directivity, for example, will only affect coupled power by 1%, and a 30 dB will be affected by only 0.1%. If the coupler is used to sample power, in both forward and reverse directions, for example, the coupled power will be correspondingly more accurate and consistent over main port mismatches the better the Directivity.

**The following table shows the coupled power versus Even Mode Impedance and Coupling angle at the center frequency:**

Coupled Power(SIN <sup>2</sup> θ)	Even mode impedance, Z <sub>oe</sub>	Coupling angle (θ)
6dB	1.7	29°
10dB	1.4	19°
15dB	1.2	10°
20dB	1.1	5°
30dB	1.03	1.7°

So a 3 dB coupler has an even mode impedance of 2.111, and  $\theta=45^\circ$  at mid band.