Topic: Rat Race Junction

Subject :Microwave Engineering

- Prajakta Upadhye
  - Asst.Professor
- GHRIET, Nagpur

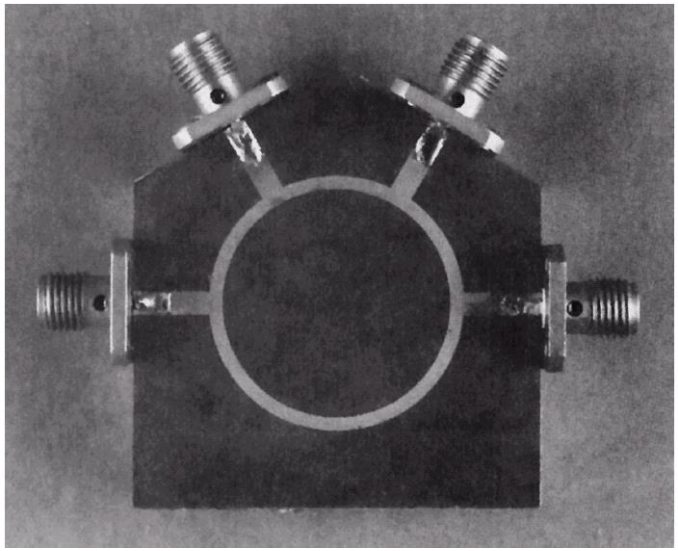
Rat-Race Ring Coupler (180° Coupler)

"Applications of rat-race couplers are numerous, and include mixers and phase shifters. The rat-race gets its name from its circular shape, shown below."

Taken from "Microwaves 101"

http://www.microwaves101.com/encyclopedia/ratrace_couplers.cfm

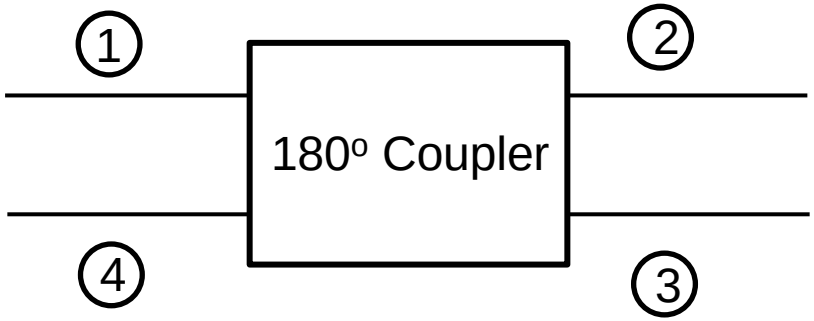




Photograph of a microstrip ring coupler

Courtesy of M. D. Abouzahra, MIT Lincoln Laboratory

Rat-Race Coupler (cont.)

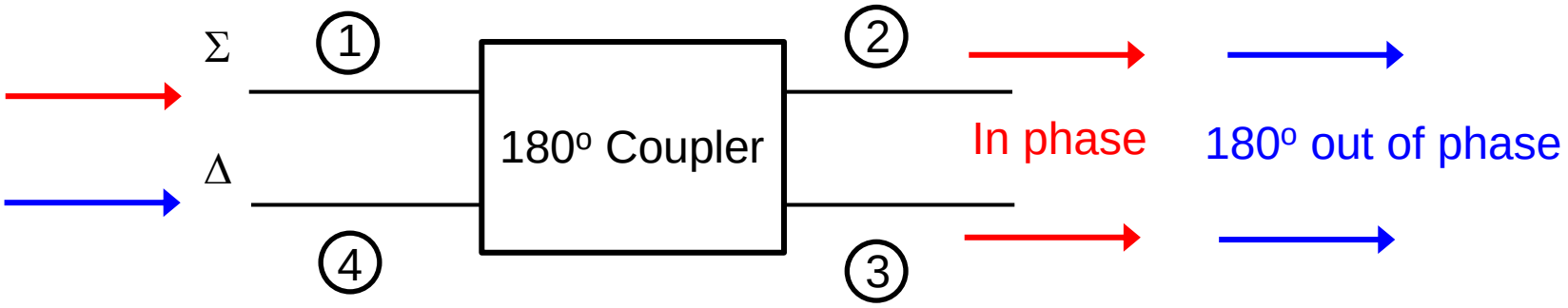


$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

- The rat race is a lossless 4-port (the S matrix is unitary).
- All four ports are matched.
- The device is reciprocal (the S matrix is symmetric).
- Port 4 is isolated from port 1, and ports 2 and 3 are isolated from each other.

Rat-Race Coupler (cont.)

The rat race can be used as a splitter:



Note: A matched load is usually placed on port 4.

- The signal from the "sum port" Σ (port 1) splits evenly between ports 2 and 3, in phase. This could be used as a power splitter (alternative to Wilkinson).

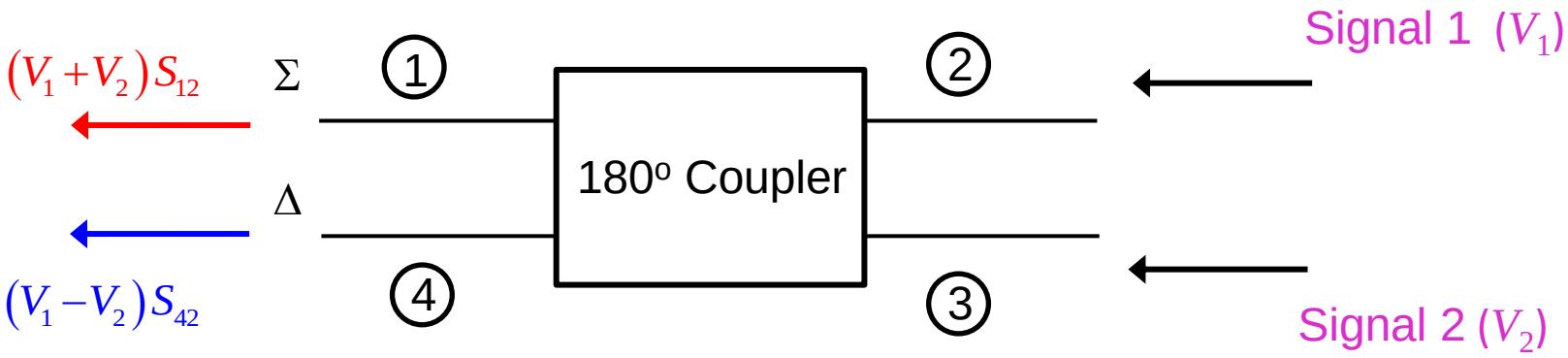
$$S_{21} = S_{31}$$

- The signal from the "difference port" Δ (port 4) splits evenly between ports 1 and 2, 180° out of phase. This could be used as a balun.

$$S_{24} = -S_{34}$$

Rat-Race Coupler (cont.)

The rat race can be used as a combiner:



- The signal from the sum port Σ (port 1) is the sum of the input signals 1 and 2.

$$S_{12} = S_{13}$$

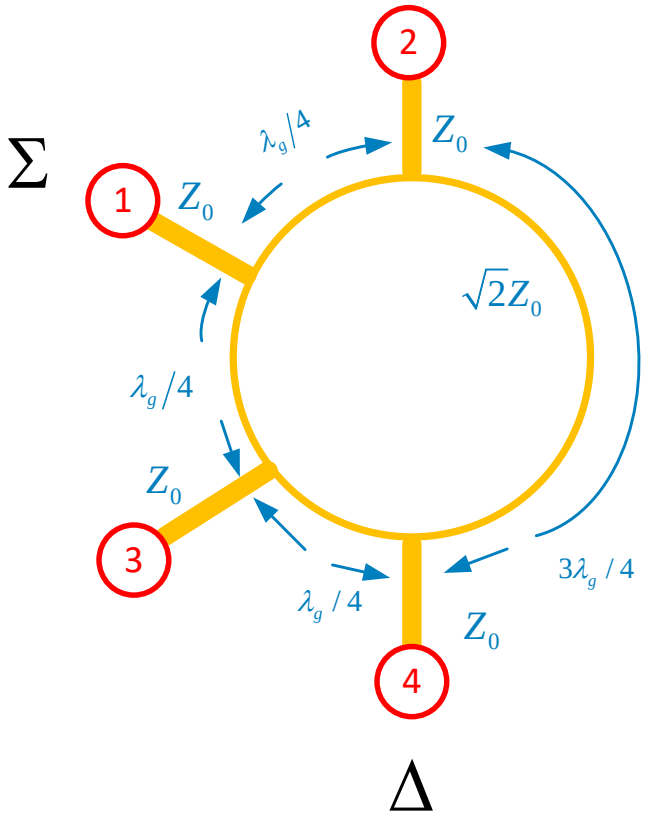
- The signal from the difference port Δ (port 4) is the difference of the input signals 1 and 2.

$$S_{42} = -S_{43}$$

Rat-Race Coupler (cont.)

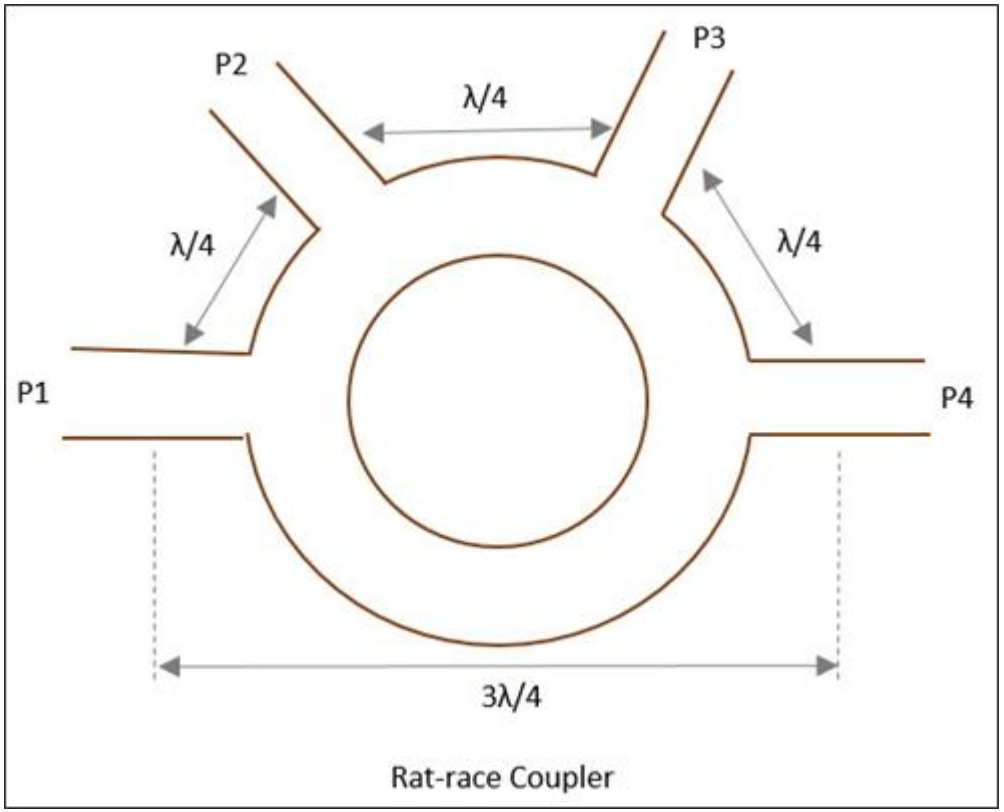
A microstrip realization is shown here.

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



Rat-Race Coupler (cont.)

This microwave device is used when there is a need to combine two signals with no phase difference and to avoid the signals with a path difference.



Operation of a Rat-race junction

Case 1

If the input power is applied at port 1, it gets equally split into two ports, but in clockwise direction for port 2 and anti-clockwise direction for port 4. Port 3 has absolutely no output.

The reason being, at ports 2 and 4, the powers combine in phase, whereas at port 3, cancellation occurs due to $\lambda/2$ path difference.

Case 2

If the input power is applied at port 3, the power gets equally divided between port 2 and port 4. But there will be no output at port 1.

Operation of a Rat-race junction

Case 3
If two unequal signals are applied at port 1 itself, then the output will be proportional to the sum of the two input signals, which is divided between port 2 and 4. Now at port 3, the differential output appears.

Applications

Rat-race junction is used for combining two signals and dividing a signal into two halves.

THANK YOU