Lab3 Report

Ye Feiyang Cao Pozhi Yuan Xiaojie

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Introduction

There are two widely used couplers, namely the Rat-Race coupler(180^o hybrid) and the Barnch-Line coupler(90^o hybrid).

For Rat-Race coupler,

$$S = \frac{-i}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 0 & -1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ -1 & 0 & 1 & 0 \end{pmatrix} \tag{1}$$

For Branch-Line coupler,

$$S = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & -i & -1 & 0 \\ -i & 0 & 0 & -1 \\ -1 & 0 & 0 & -i \\ 0 & -1 & -i & 0 \end{pmatrix} \tag{2}$$

The rat-race coupler has four ports, each placed one quarter wavelength away from each other around the top half of the ring. The bottom half of the ring is three quarter wavelengths in length. The ring has a characteristic impedance of factor compared to port impedance. A rat-race coupler (also known as a hybrid ring coupler) is a type of coupler used in RF and Microwave systems. It has the advantage of being easy to realize in planar technologies such as microstrip and stripline, although waveguide rat races are also practical.

The branch-line coupler consists of two parallel transmission lines physically coupled together with two or more branch lines between them. The branch lines are spaced $\lambda/4$ apart and represent sections of a multi-section filter design in the same way as the multiple sections of a coupled line coupler except that here the coupling of each section is controlled with the impedance of the branch lines. Coupled lines are a better choice when loose coupling is required, but branch-line couplers are good for tight coupling and can be used for 3 dB hybrids. Branch-line couplers usually do not have such a wide bandwidth as coupled lines.

Simulation

From "Figure 1", $dB(S(1,1)) = dB(S(1,4)) \approx -60$ which means that there is no reflection at port1 and also port4 is isolated. On the other hand, $dB(S(1,2)) = dB(S(1,3)) = 3$ which means that the total power is equally

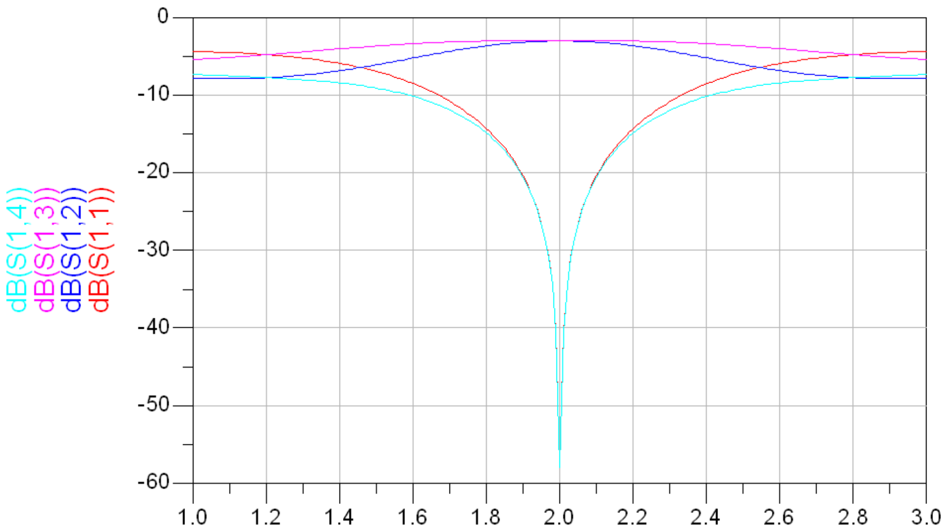

Figure 1: S(1,n) of Rat-Race coupler

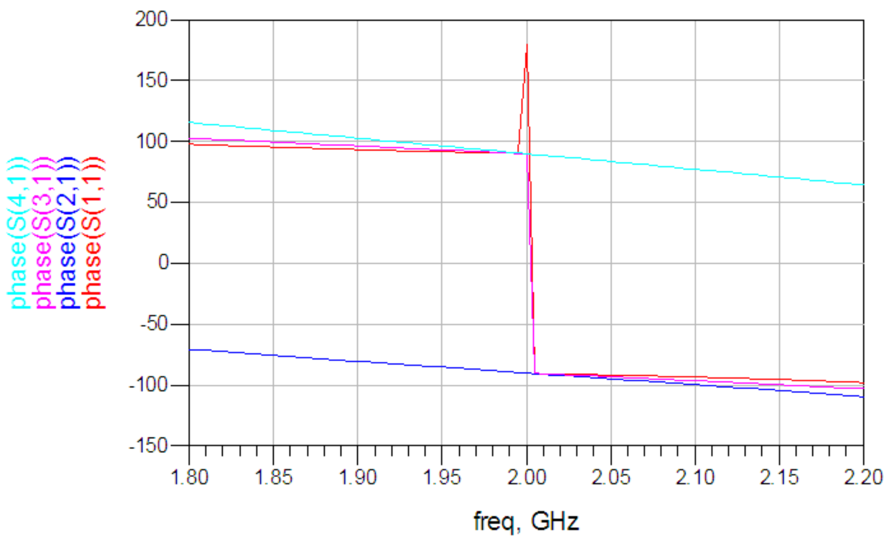

Figure 2: phase of Rat-Race coupler

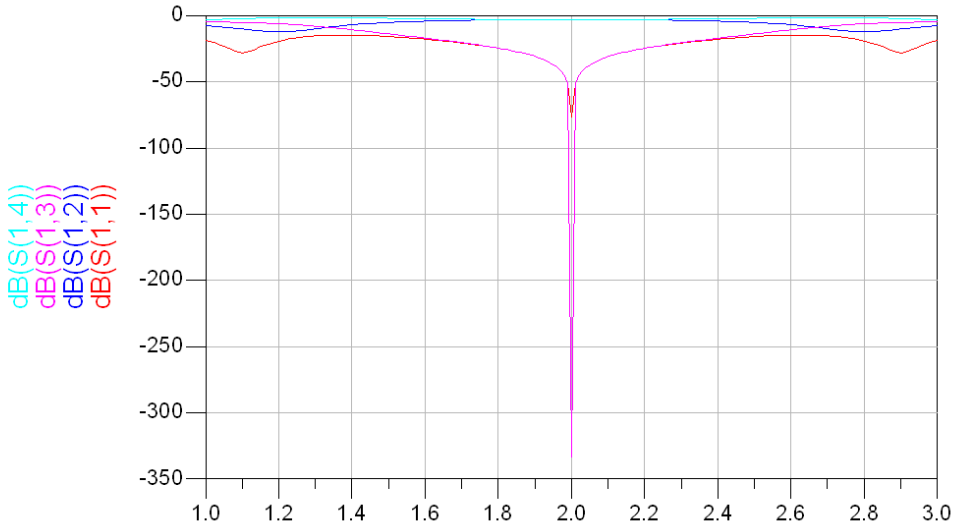

Figure 3: S(1,n) of Branch-Line coupler

splitted and transmitted to port2&3.

Similarly, from "Figure 3", $dB(S(1,1)) = dB(S(1,3)) \approx -300$ which means that there is no reflection at port1 and also port4 is isolated. On the other hand, $dB(S(1,2)) = dB(S(1,4)) = 3$ which means that the total power is equally splitted and transmitted to port2&4.

Compare the transmission phase with the S parameters shown above. These values are all expected and correct.

Then, by comparing the transmission phase between coupled ports of these two kinds of couplers, it is clear that for Rat - Race couplers, which is also named as 180 coupler, the phase difference between two coupled ports, port 2 and port 4, is 180. And for Branch - Line couplers, which is also named as 90 coupler, the phase difference between the coupled ports, port 2 and port 3, is 90.

For a 3dB Rat-Race at 1.8GHz, we simulated within the range of 1.6GHz to 2GHz. With the parameters of microstrip line, the length and width of each transmission line is calculated. We get that for those lines with length $\lambda/4$, the actual length should be 1004.3 mil and the actual width should be 72.08 mil. And for the one with length $3/4\lambda$, the actual length should be 3012.9 mil and the simulation result is shown on "Figure 5" and "Figure 6".

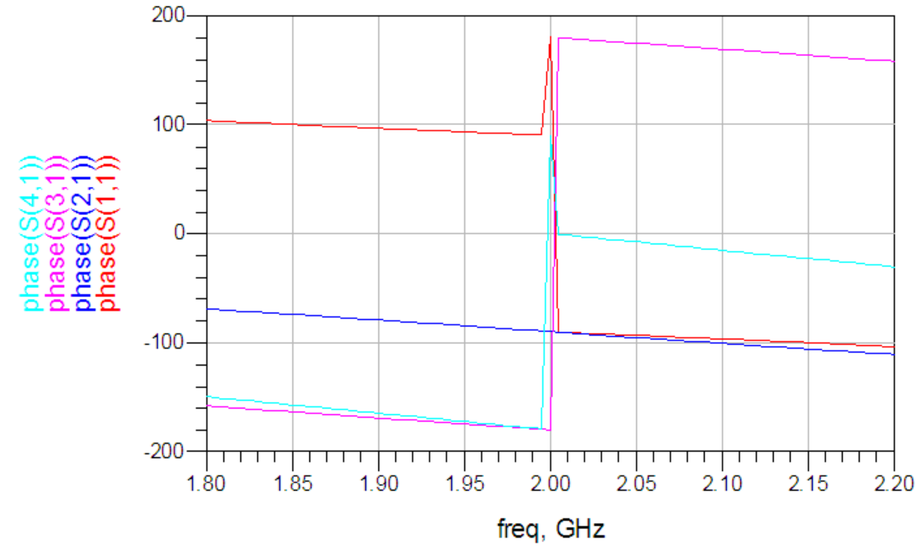

Figure 4: phase of Branch-Line coupler

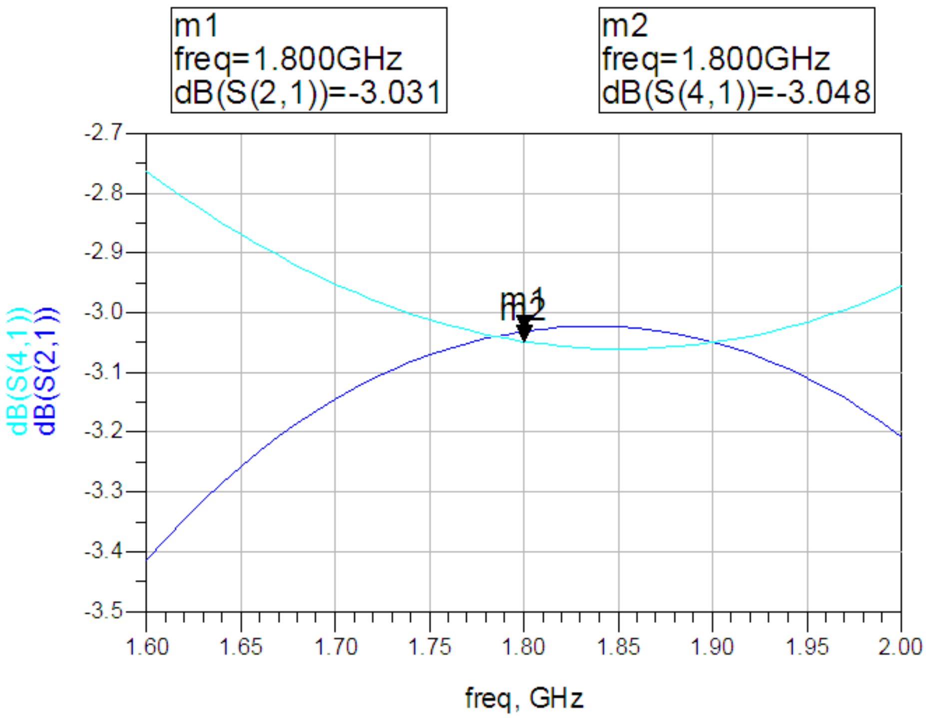

Figure 5: S of microstripe line simulation

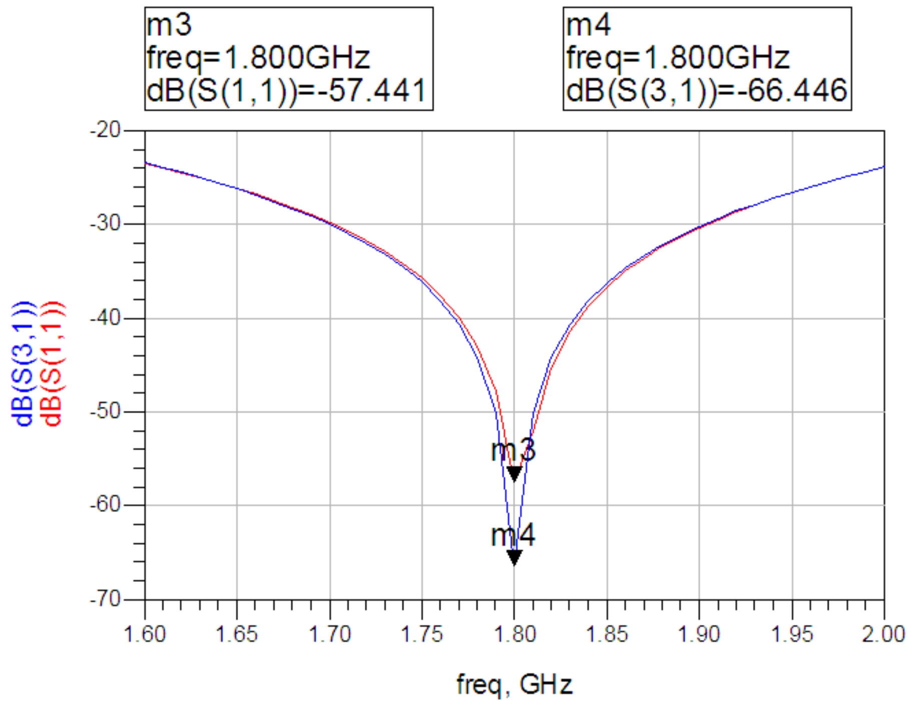

Figure 6: phase of microstripe line silmulation

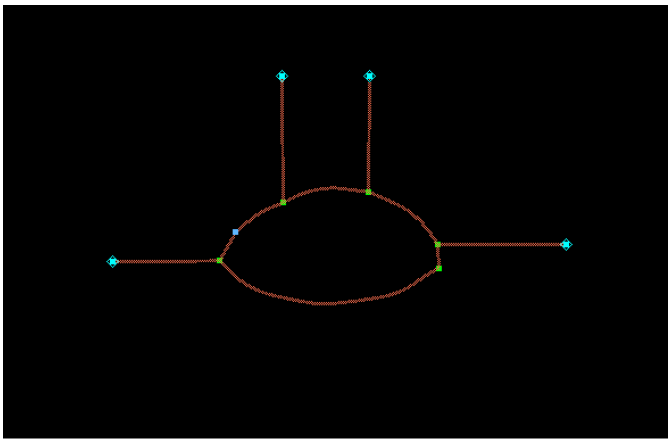

Figure 7: Layout of Rat-Race coupler

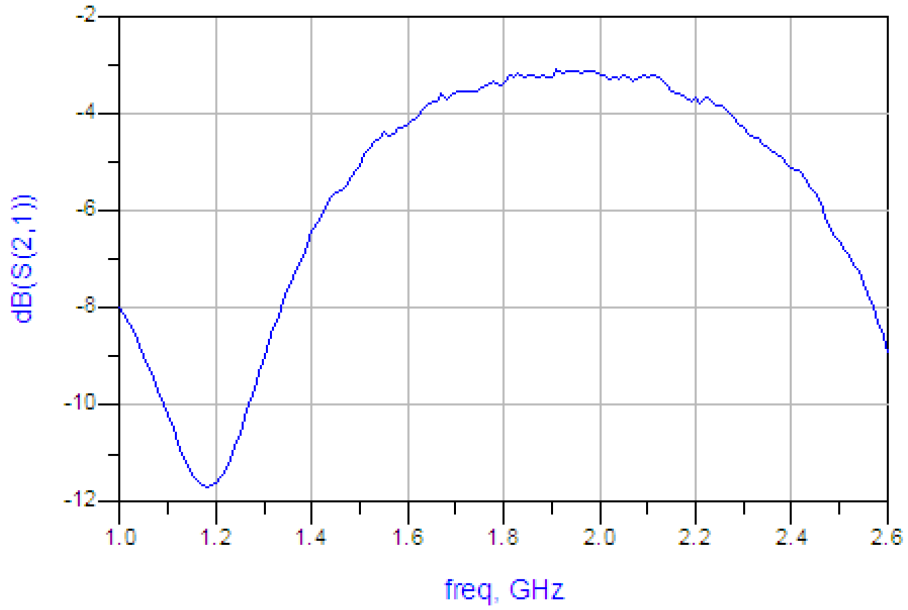

Figure 8: S(1,2) of Rat-Race coupler

Data& Analysis

After measure the real circuit at 2GHz using VNA, we get three .s2p files which represent S_12 S_13 and S_14 respectively.

From the "Figure 8 10", at 2GHz, $dB(S12) = 3$, $dB(S13) = 3$ and $dB(S14 = -40)$. Therefore, the total input power at port1 is equally distributed to port2&3 and port4 is isolated without power received.

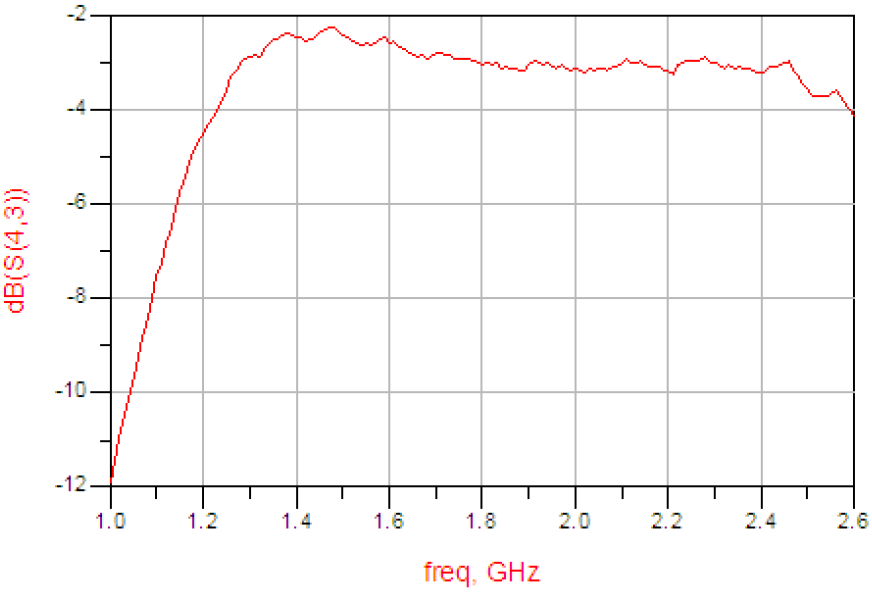

Figure 9: S(1,3) of Rat-Race coupler

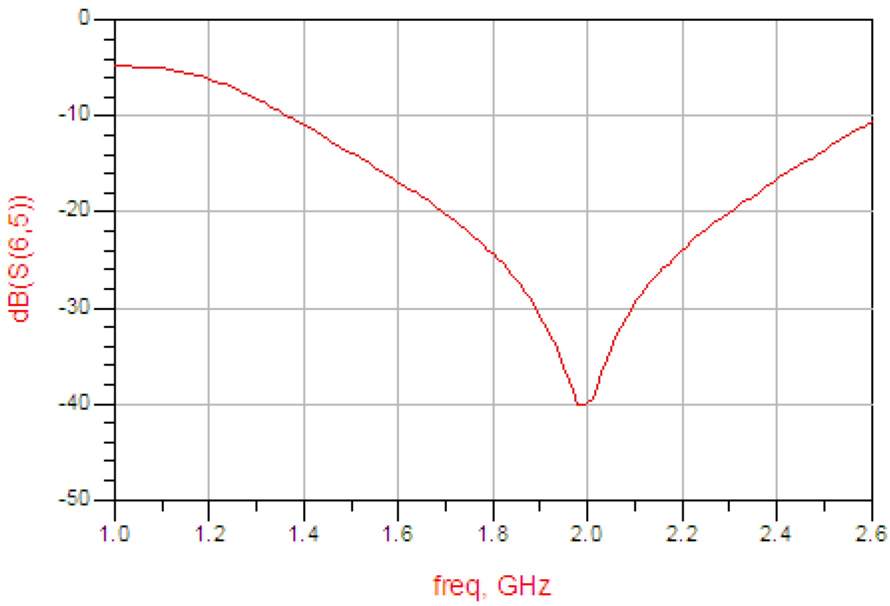

Figure 10: S(1,4) of Rat-Race coupler