Xidian University & Heriot-Watt University

Design and Measurement of a Microstrip Branch-Line Coupler

(B39HF | B31HD)

High Frequency Circuit Design

Team Members:

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1. Aims and Objectives

The first goal of this experiment is to use Keysight ADS to design and simulate a 3 dB hybrid branch line coupler in microstrip technology using an FR4 substrate. The second objective is to measure the performance of your fabricated design using a USB-based Vector Network Analyzer (VNA).

2. Background Theory

A branch line coupler (see Fig. 1) can be designed to yield any coupling level, not just 3 dB (a 3-dB coupler is called a “hybrid coupler”). For an ideal and lossless coupler such as this, there should be an equal 3 dB power split between the output ports and a 90-degree phase difference.

3.Experimental Equipment

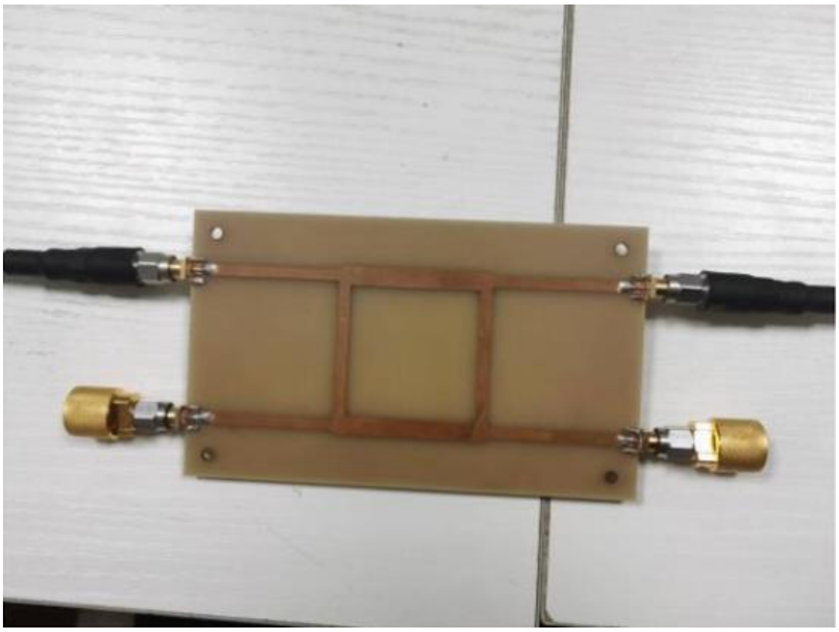

Figure 1. A branch-line coupler made of copper.

4. Experimental Procedure

In this lab, a 3dB hybrid branch line coupler was tested to evaluate its performance characteristics. Additionally, the coupler was designed and simulated in Keysight's ADS software to compare against the measured results.

The hybrid coupler is an important microwave component that can split an input signal into two output signals with a defined 90-degree phase shift between them. This functionality is useful for balanced mixer and oscillator circuits.

The 3dB lab coupler was designed to meet specific requirements including equal split ratio between outputs, port isolation greater than 20dB return loss, and tight phase balance. The device was fabricated on an FR4 substrate material using microstrip.

Testing was conducted through vector network analyser measurements on the fabricated coupon. All four S-parameters were collected to assess input match, coupling ratio, phase difference, and isolation. These measured results were then compared side-

by-side with those predicted in the ADS simulation model.
This procedure provided insight into how accurate our theoretical designs match real-world fabricated performance. It also demonstrated the overall functionality of the 3dB hybrid coupler through evaluation of key parameters against specification. Both simulation and measurement processes offered valuable learning experiences in high frequency component design.

5. Results (VNA)

The 3dB hybrid branch line coupler that we tested is shown below.

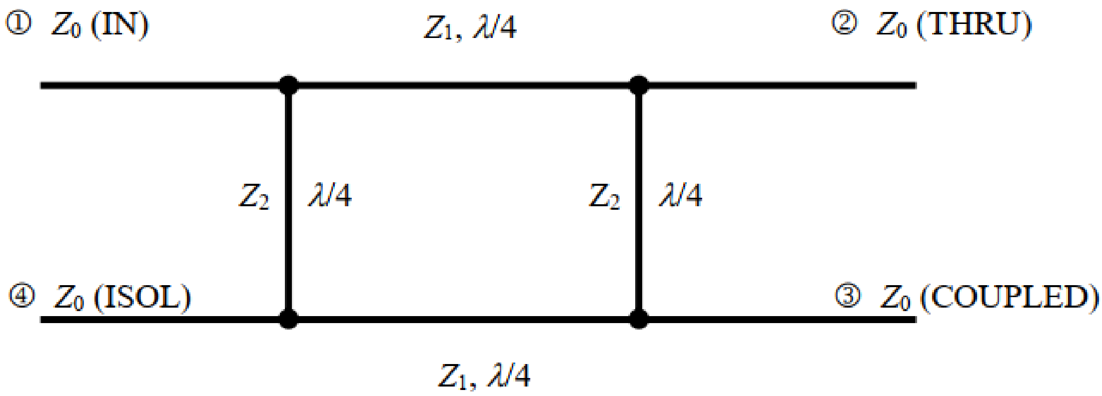

Figure 2. A branch-line coupler with the coupling port defined as port.

The 4 S-parameters of this 3dB hybrid branch line coupler is:

- S11 (Input Port Return Loss): Less than -20dB. This indicates the input port should be well matched to 50 ohms.
- S21 (Through Port Transmission): Around -3dB. This indicates around half the input power (-3dB) is transferred to the through port.
- S31 (Coupled Port Transmission): Around -3dB. This also indicates around half the input power (-3dB) is coupled to the coupled port.
- S41 (Isolated Port Transmission): Less than -20dB. This port should isolate the input from the coupled output, so very little power should reach it.

Additionally, S21 and S31 should have a 90-degree phase difference between them.

To evaluate its performance characteristics, we need to test its S-parameters and the phase of S21 and S31, then calculate the phase difference.

Firstly, calibrate the VNA, then start the measurement.

Here are the results.

(i) S11

Measuring the S11, port 1 connect to the input signal and other three ports connect 50Ω impedance.

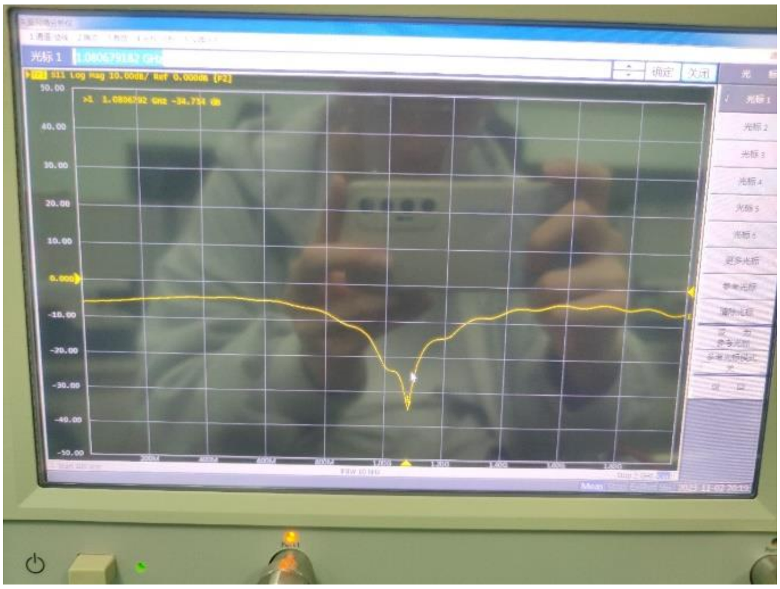

Figure 3. Result of S11

The measuring result is -34.754dB which is less than -20dB.

Meet the lab requirement.

(ii) S21

Measuring the S21, port 1 connect to the input signal and port 2 to connect to the output, other two ports connect 50Ω impedance.

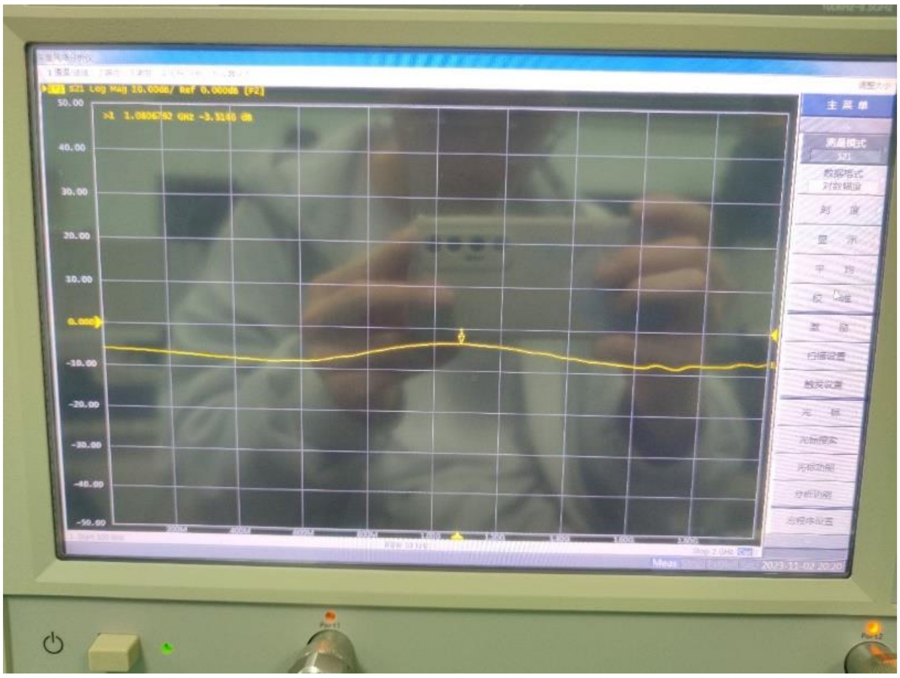

Figure 4. Result of S21

The measuring result is -3.5146dB which is around -3dB.

Meet the lab requirement.

(iii) S31

Measuring the S31, port 1 connect to the input signal and port 3 to connect to the output, other two ports connect 50Ω impedance.

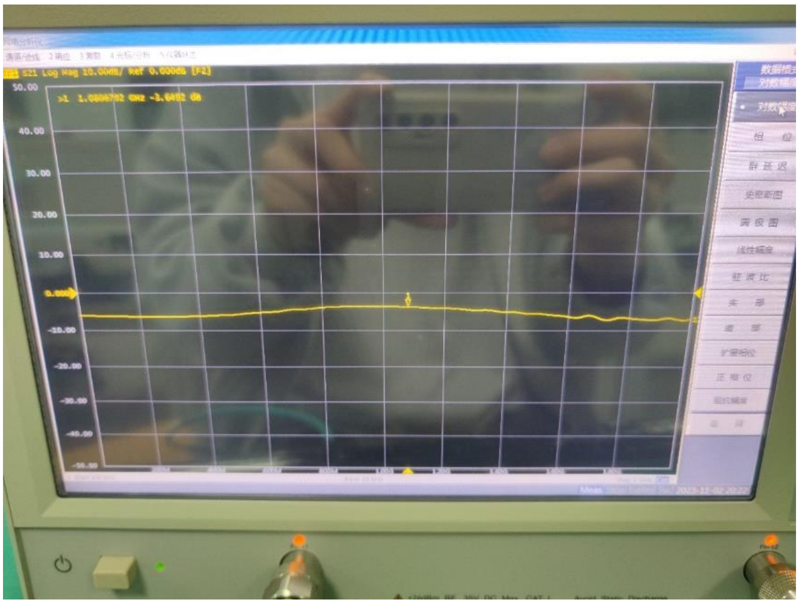

Figure 5. Result of S31

The measuring result is -3.6492dB which is around -3dB.

Meet the lab requirement.

(iv) S41

Measuring the S41, port 1 connect to the input signal and port 4 to connect to the output, other two ports connect 50Ω impedance.

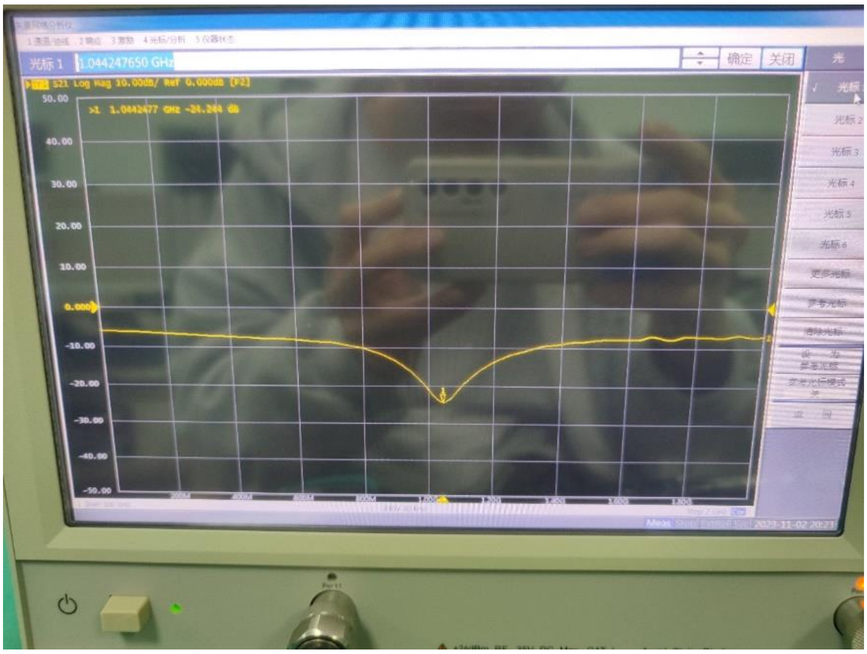

Figure 6. Result of S41

The measuring result is -24.244dB which is less than -20dB.

Meet the lab requirement.

(a) Phase of S21

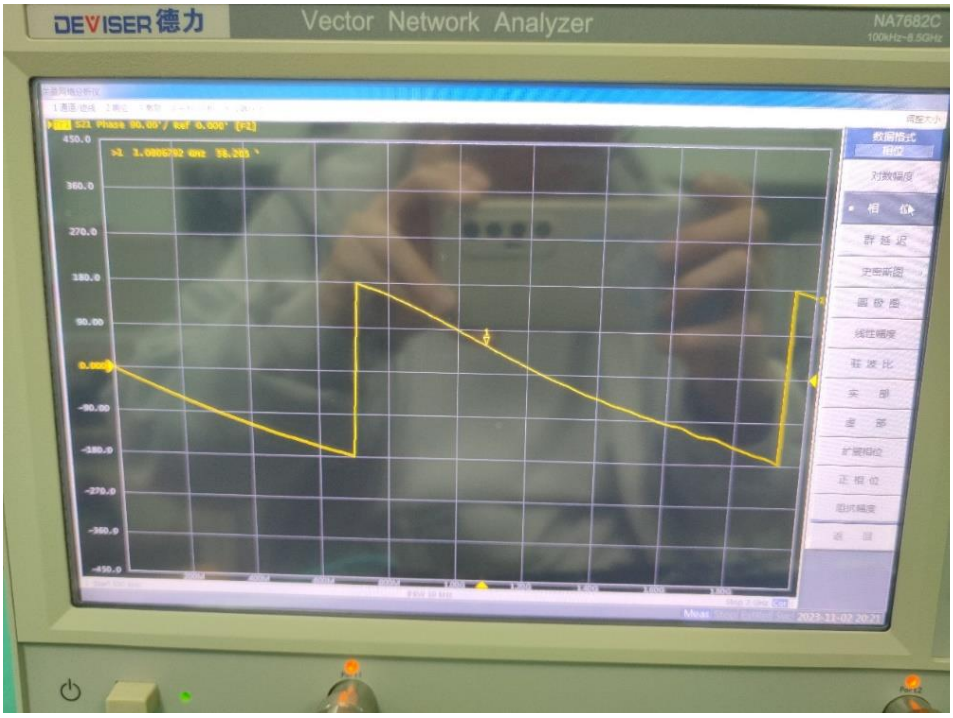

Figure 7. Result of phase of S21

(b) Phase of S31

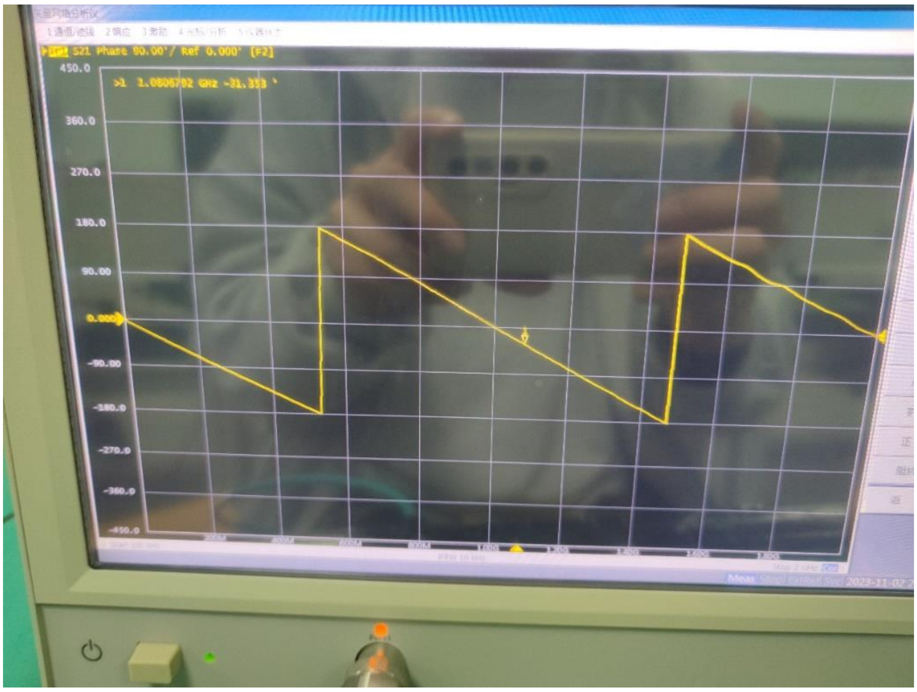

Figure 8. Result of phase of S31

The measuring results are:

Table 1. Measuring results

S11	-34.754dB
S21	-3.5146dB
S31	-3.6492dB
S41	-24.244dB
Phase of S21	58.205°
Phase of S31	-31.353°
Phase difference between S21 and S31	89.558°

5. Results(Simulating)

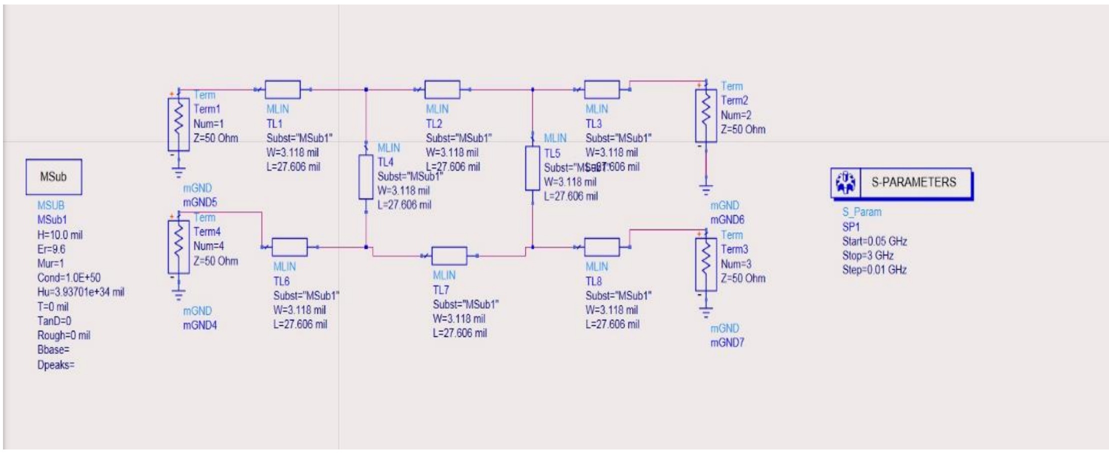

Figure 9. the initial circuit without optimize

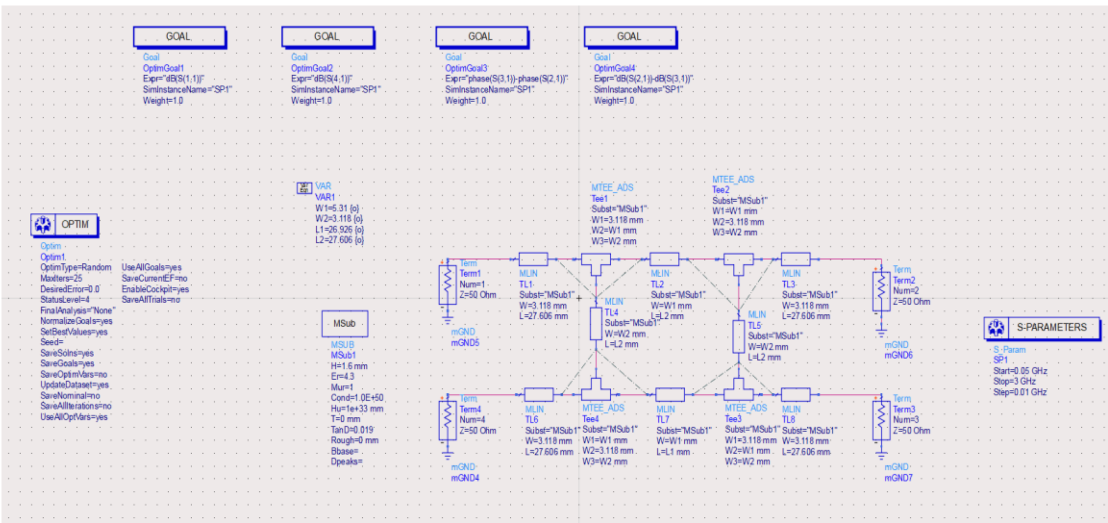

Figure 10.the circuit with optimize

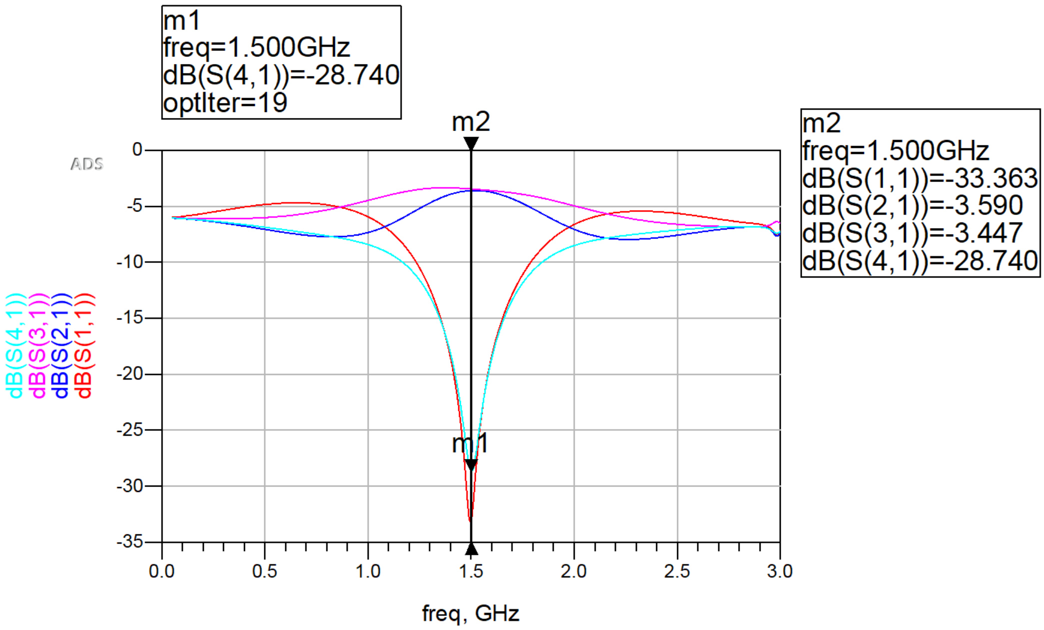

Figure 11.the wave of the S (1,1)-S (4,1)

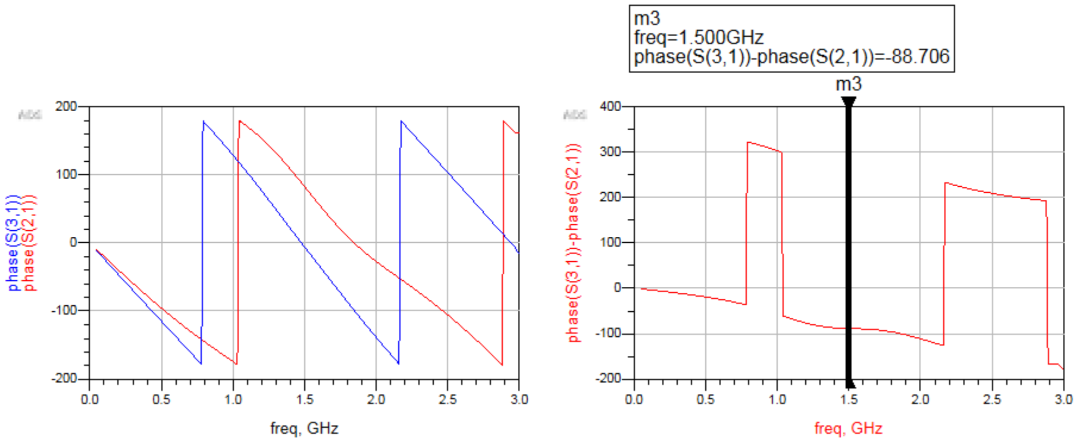

Figure 12.the phase and the difference between the S (1,1)-S (4,1)

6.Conclusion and Analysis

For an ideal and lossless coupler such as this, there should be an equal 3 dB power split between the output ports and a 90-degree phase difference. And within a reasonable error range, our experimental results are in line with the expected value. As for the part that can still be optimized, we can still make further optimization to obtain more accurate values at the T-shaped trifurcated circuit port.

7.Reference

B39HF B31HD Labratory 4 - Hybrid Coupler Design

B39HF lecture 12-14