



Indian Institute of Technology Bombay

EE611 : Microwave Integrated Circuits
2022-23/I

Broadband 4 x 4 Butler Matrix

Group 3

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Project Objective

Design a Broadband 4X4 Butler Matrix Circuit Using Microstrip Transmission line using the following specifications.

Specifications :

Frequency of operation = 5.4GHz

Substrate type : FR-4

$\epsilon_r = 4.4$

$h = 1.6\text{mm}$

$\tan\delta = 0.02$

$T = 35\mu\text{m}$

Project Report

November 04, 2022

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1. Designing a 90^0 hybrid using Transmission Lines

1.1 Schematic for 90^0 hybrid using Transmission Lines

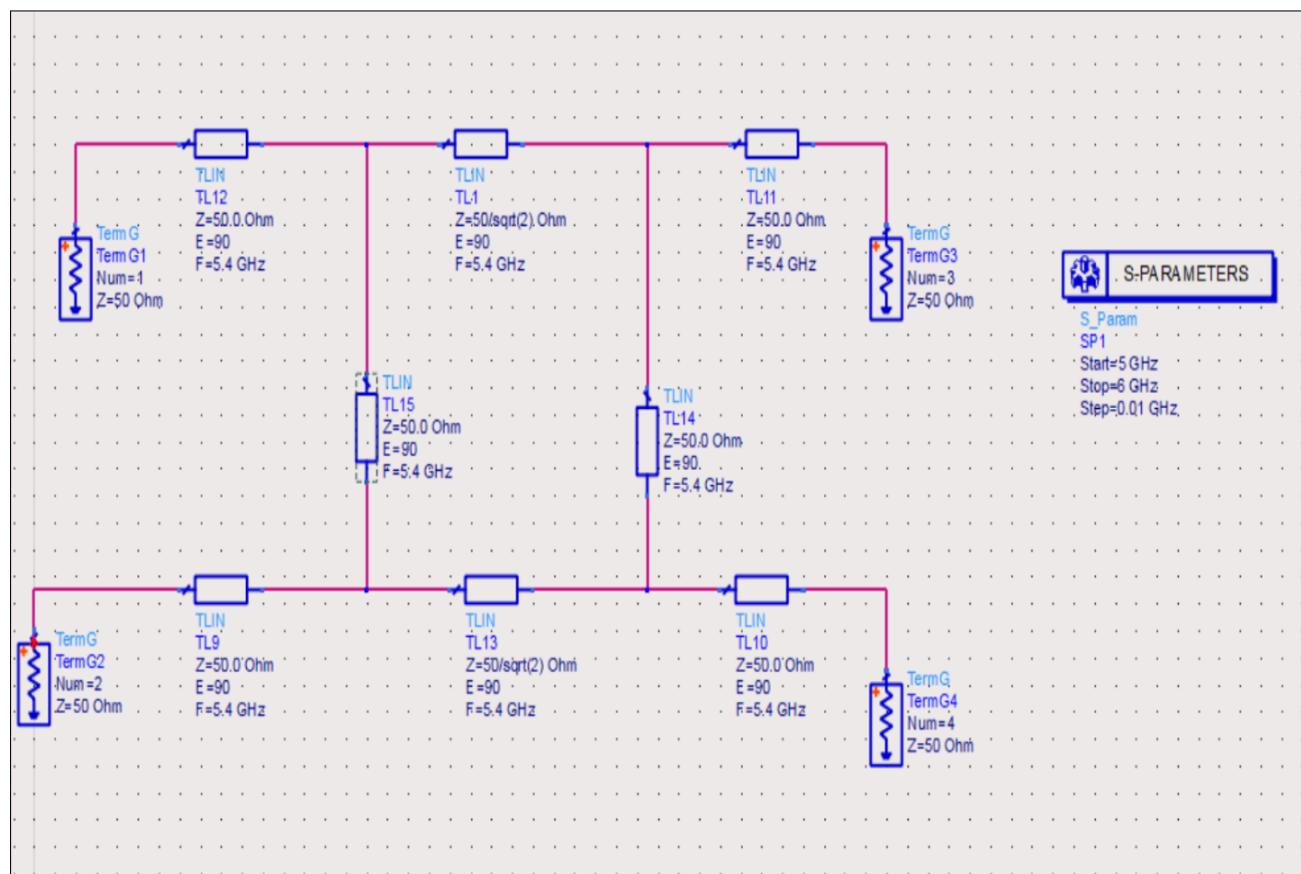


Fig. 1 : Schematic for 90^0 hybrid using Transmission Lines

1.2 Simulation Results for 90^0 hybrid using Transmission Lines

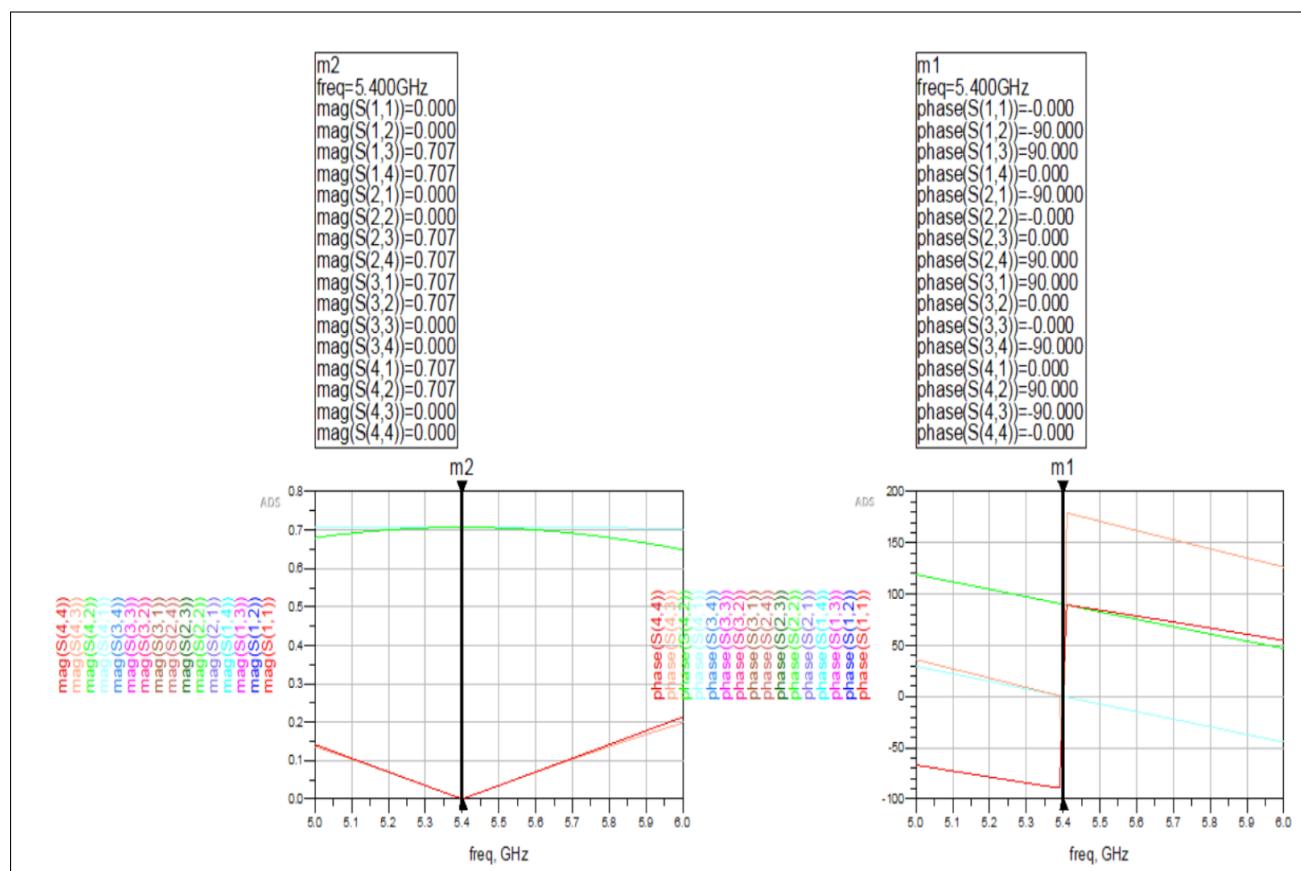


Fig. 2 : Simulation Results of 90^0 hybrid using Transmission Lines

2. Designing a 90^0 hybrid using Microstrip Transmission Lines

2.1 Schematic for 90^0 hybrid using Microstrip Transmission Lines

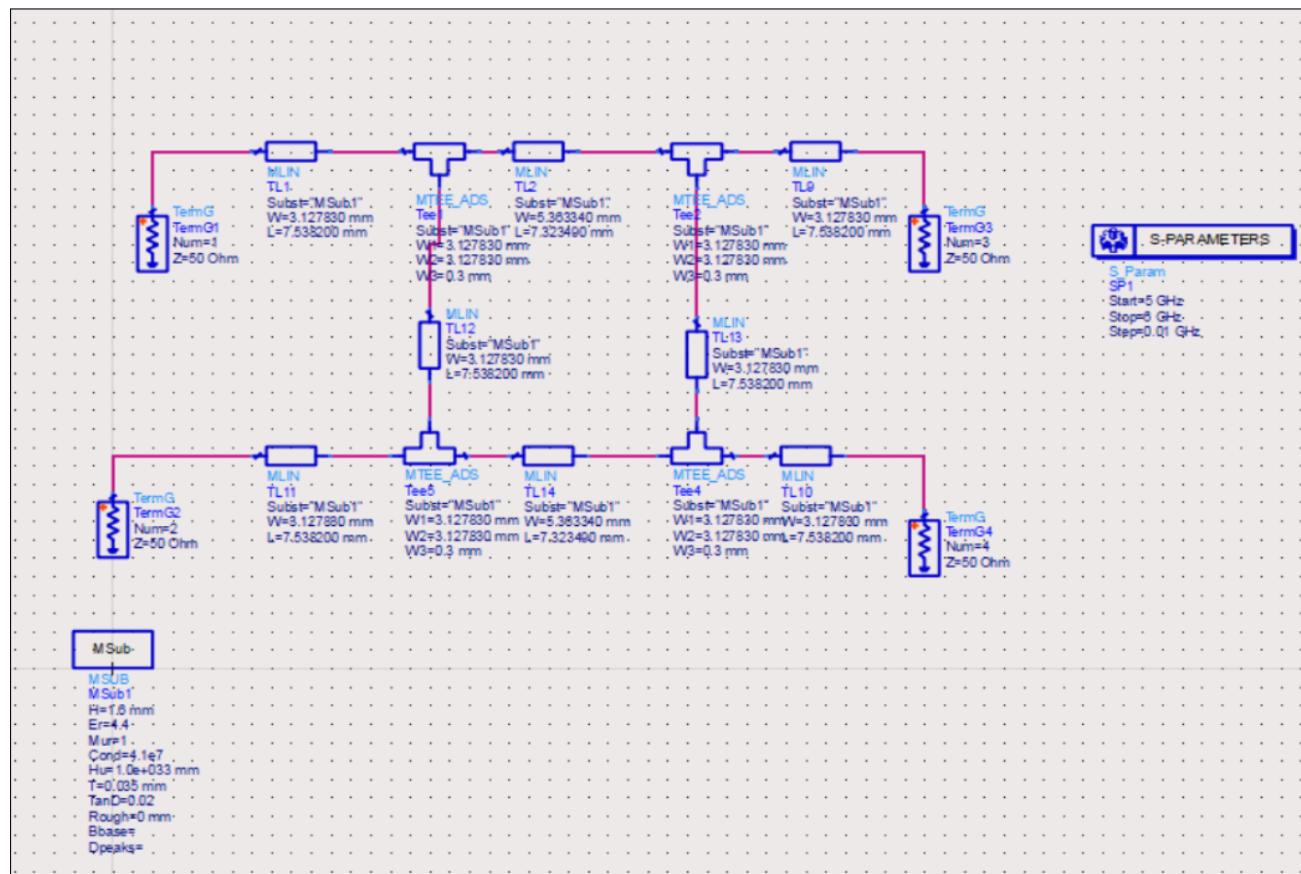


Fig. 3 : Schematic for 90^0 hybrid using Microstrip Transmission Lines

2.2 Simulation Results of 90^0 hybrid using Microstrip Transmission Lines

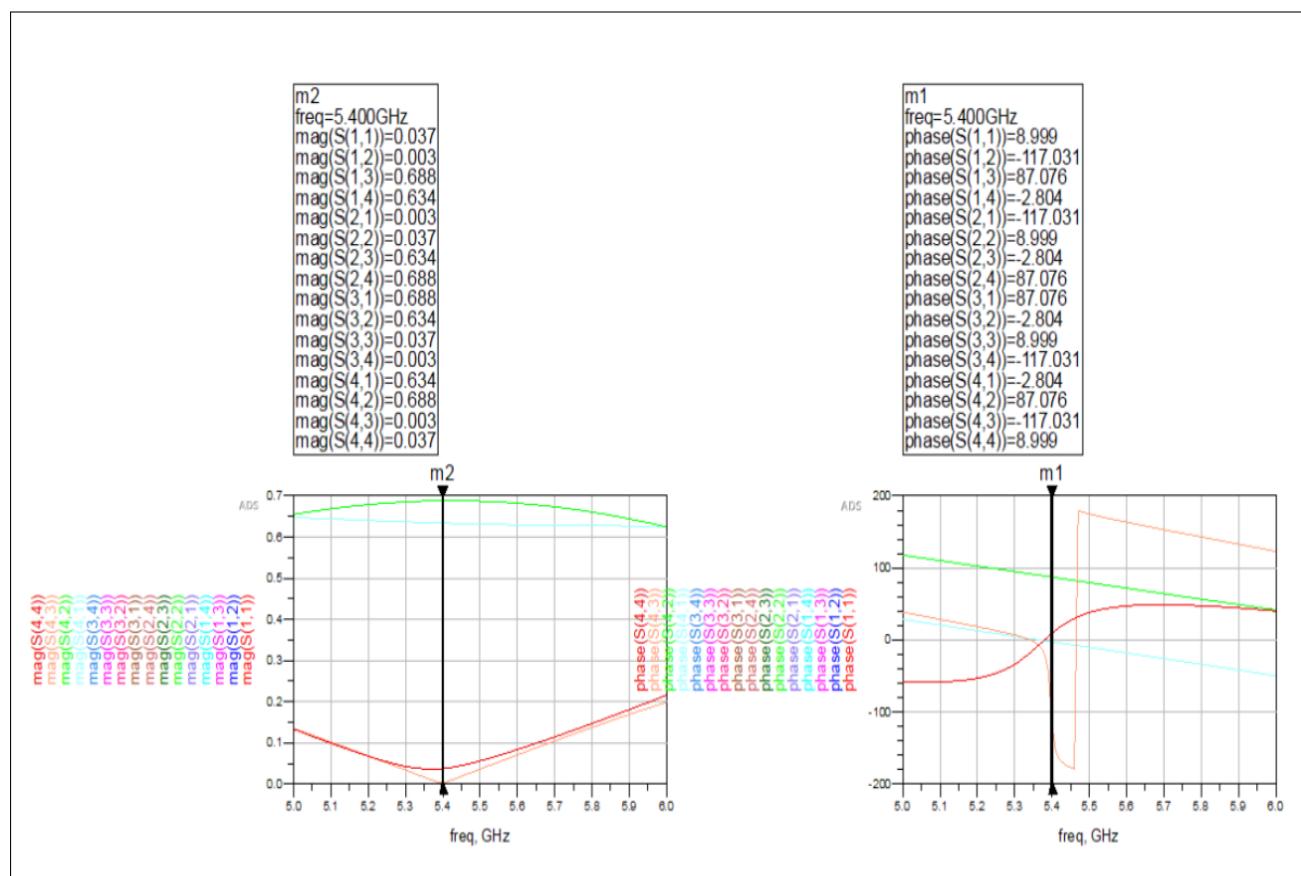


Fig. 4 : Simulation Results of 90^0 hybrid using Microstrip Transmission Lines

3. Designing the Butler Matrix 4×4 on ADS schematics using Transmission Lines

3.1 Transmission Line Butler Matrix schematic

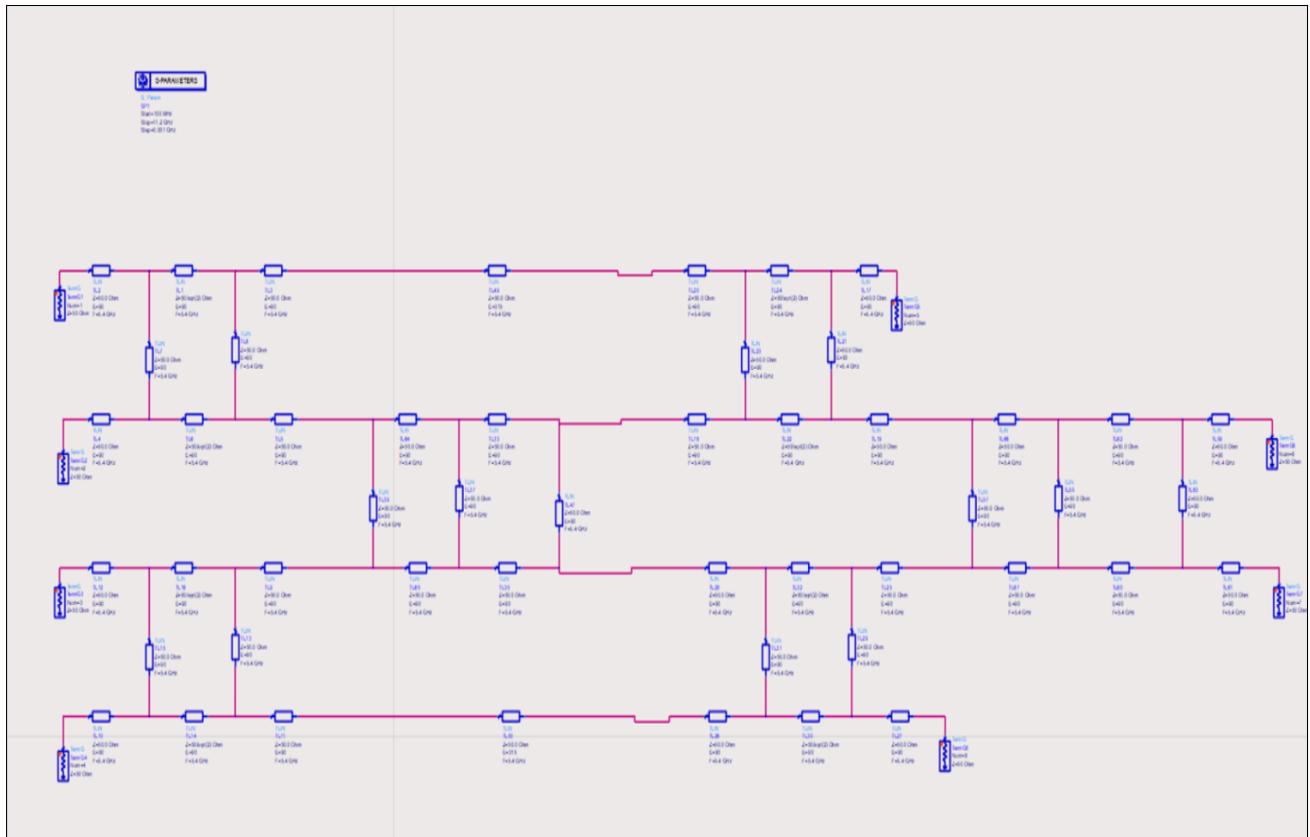


Fig. 5 : 4×4 Butler Matrix on ADS schematics using Transmission Lines

3.2 Simulation Results of 4×4 Butler Matrix on ADS schematics using Transmission Lines

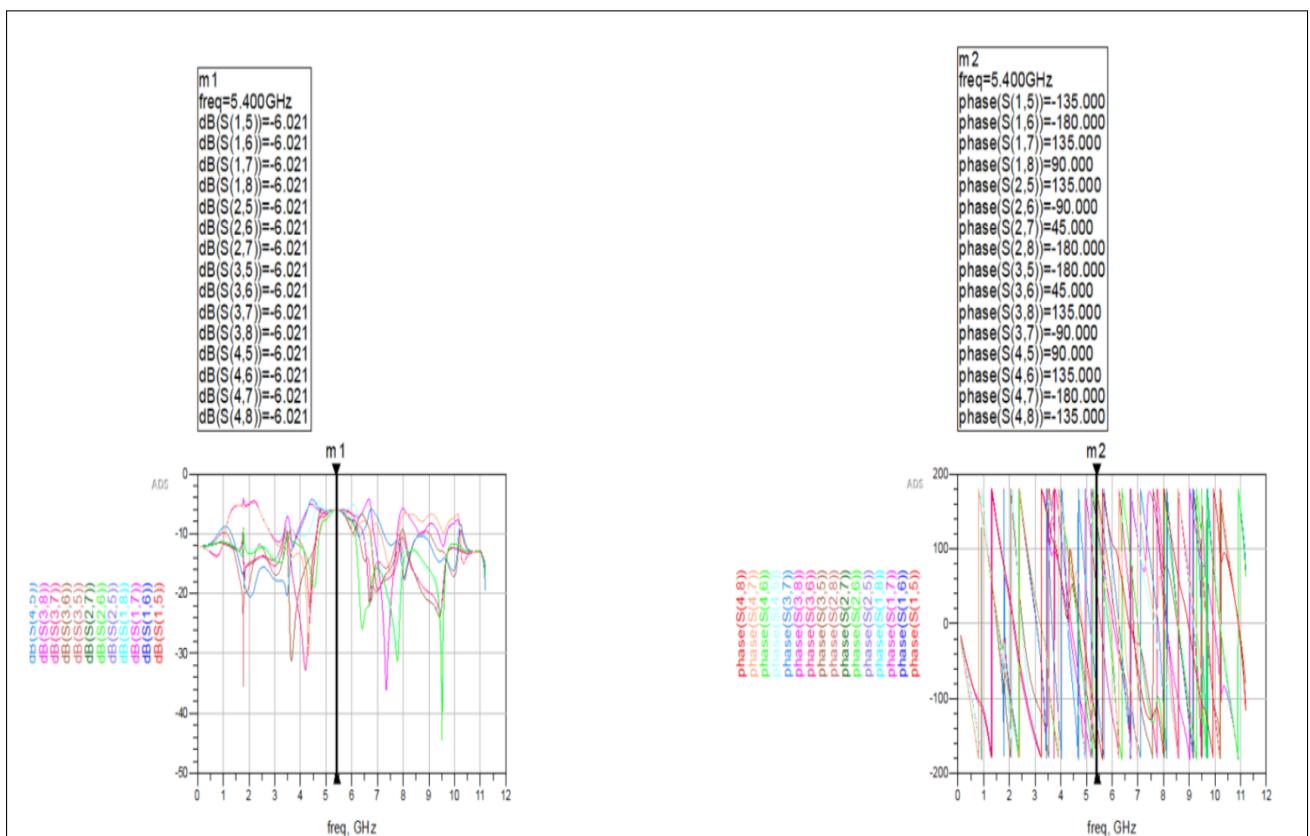


Fig. 6 : Simulation Results of 4×4 Butler Matrix on ADS schematics using Transmission Lines

4. Designing the Butler Matrix 4×4 on ADS schematics using Microstrip Transmission Lines

4.1 Microstrip Transmission Lines Butler Matrix schematic

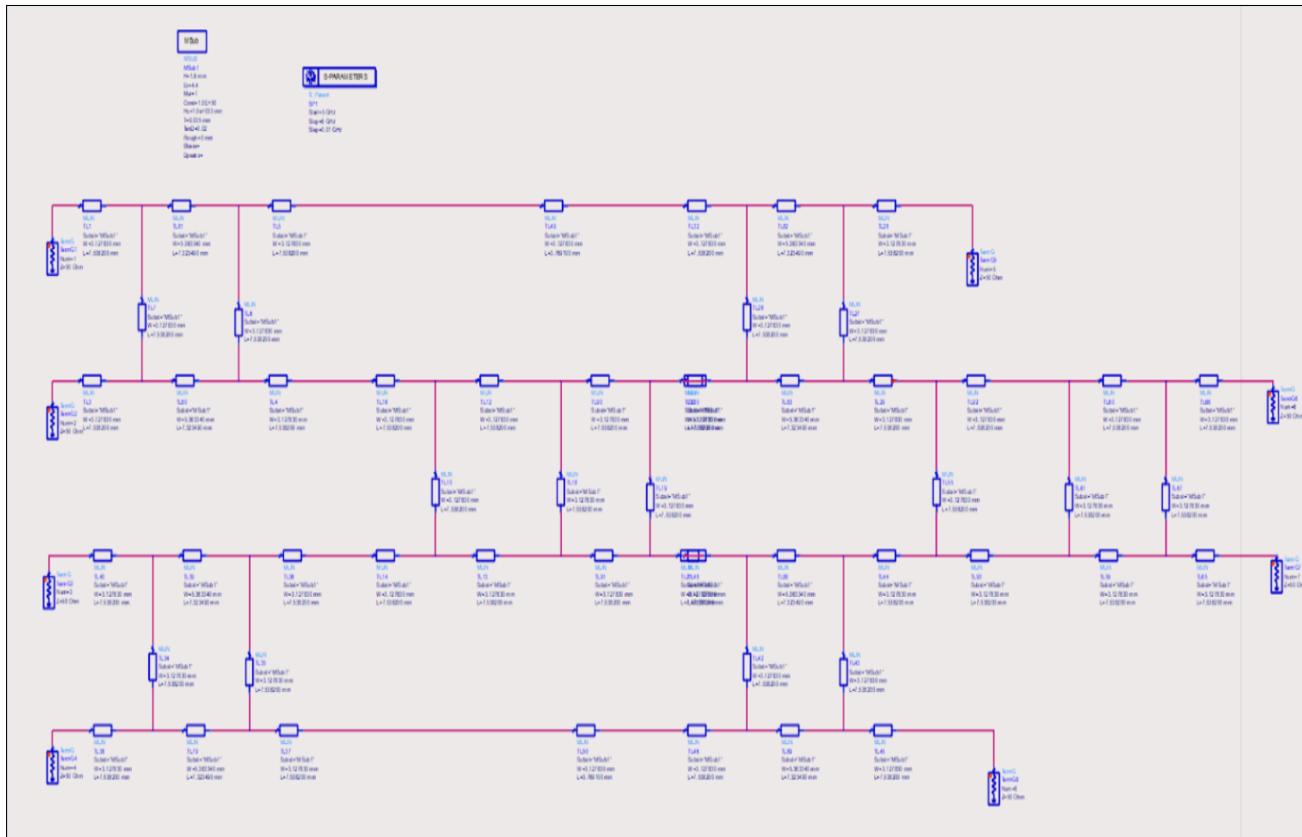


Fig. 7 : 4×4 Butler Matrix on ADS schematics using Microstrip Transmission Lines

4.2 Simulation Results of 4×4 Butler Matrix on ADS schematics using Microstrip Transmission Lines

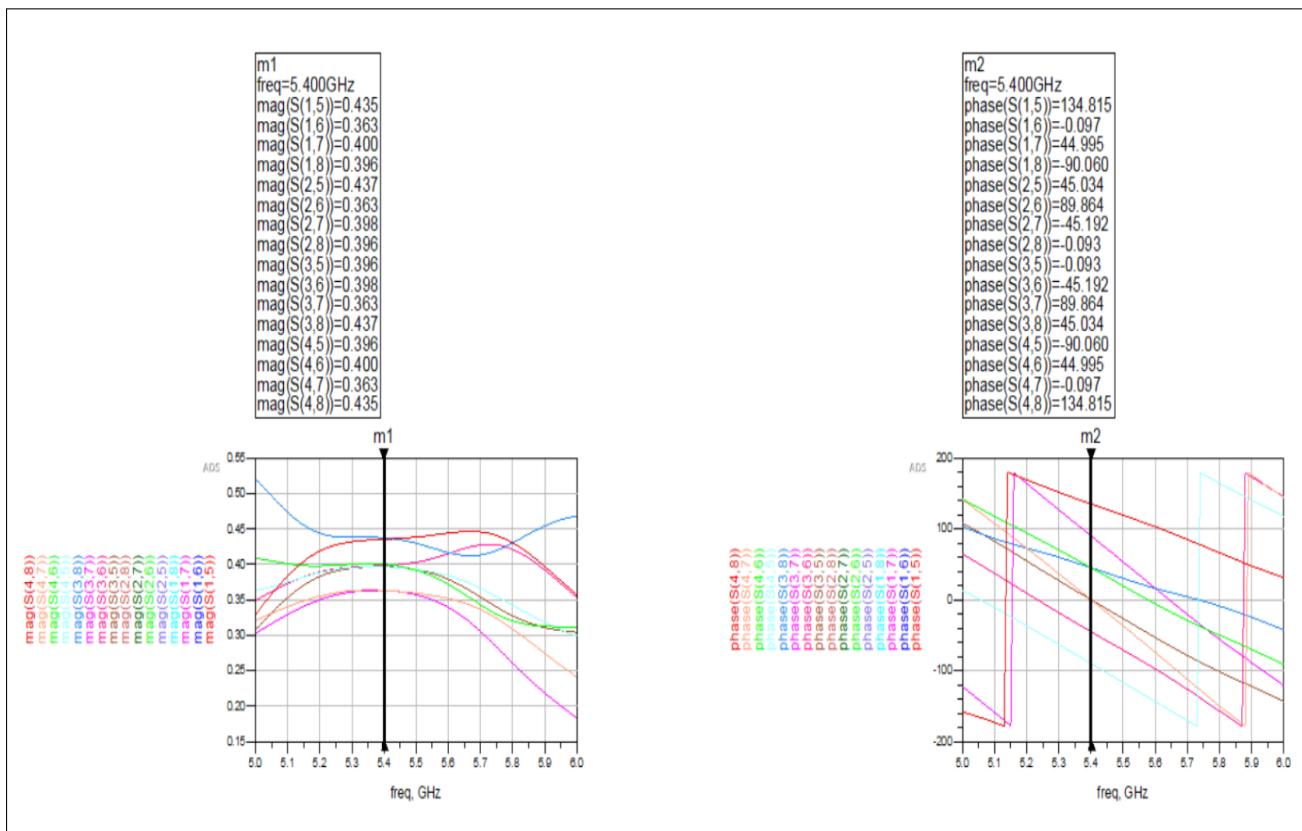


Fig. 8 : Simulation Results of 4×4 Butler Matrix on ADS schematics using Microstrip Transmission Lines

5. Corrected design of the Butler Matrix 4×4 using Microstrip Transmission Lines

5.1 Corrected Microstrip Transmission Lines Butler Matrix schematic

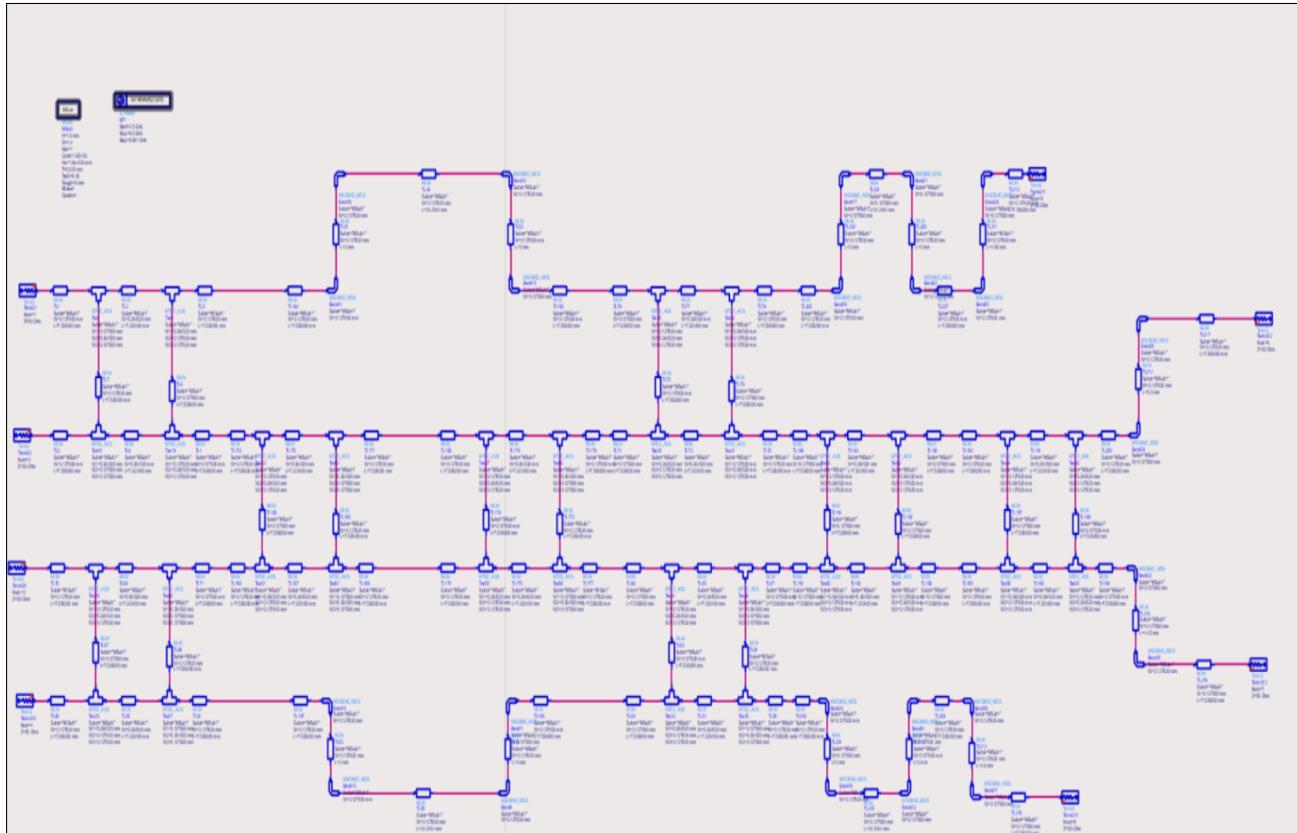


Fig. 9 : 4×4 Butler Matrix on ADS schematics using Microstrip Transmission Lines

5.2 Simulation Results of corrected design of the Butler Matrix 4×4 using Microstrip Transmission Lines

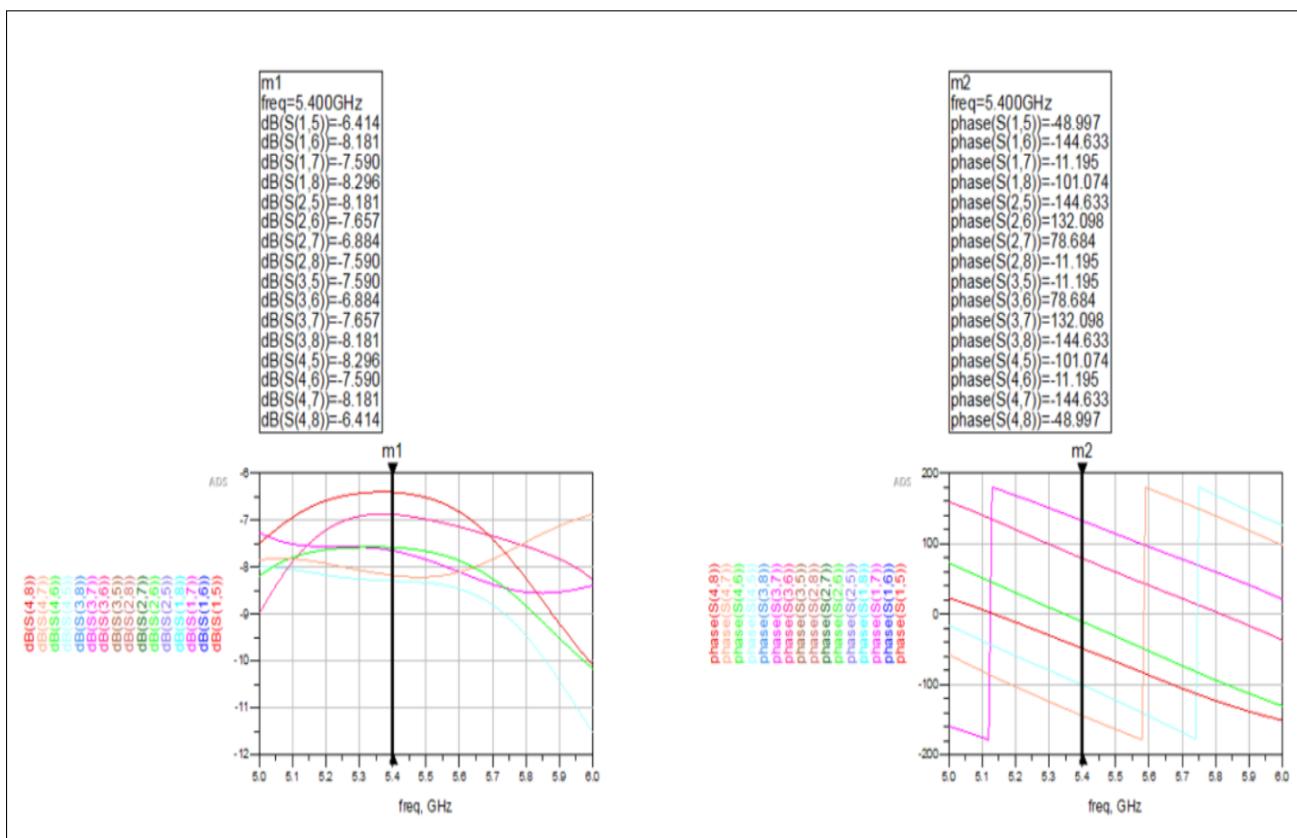


Fig. 10 : Simulation Results of corrected design of the Butler Matrix 4×4 using Microstrip Transmission Lines

5.3 Layout

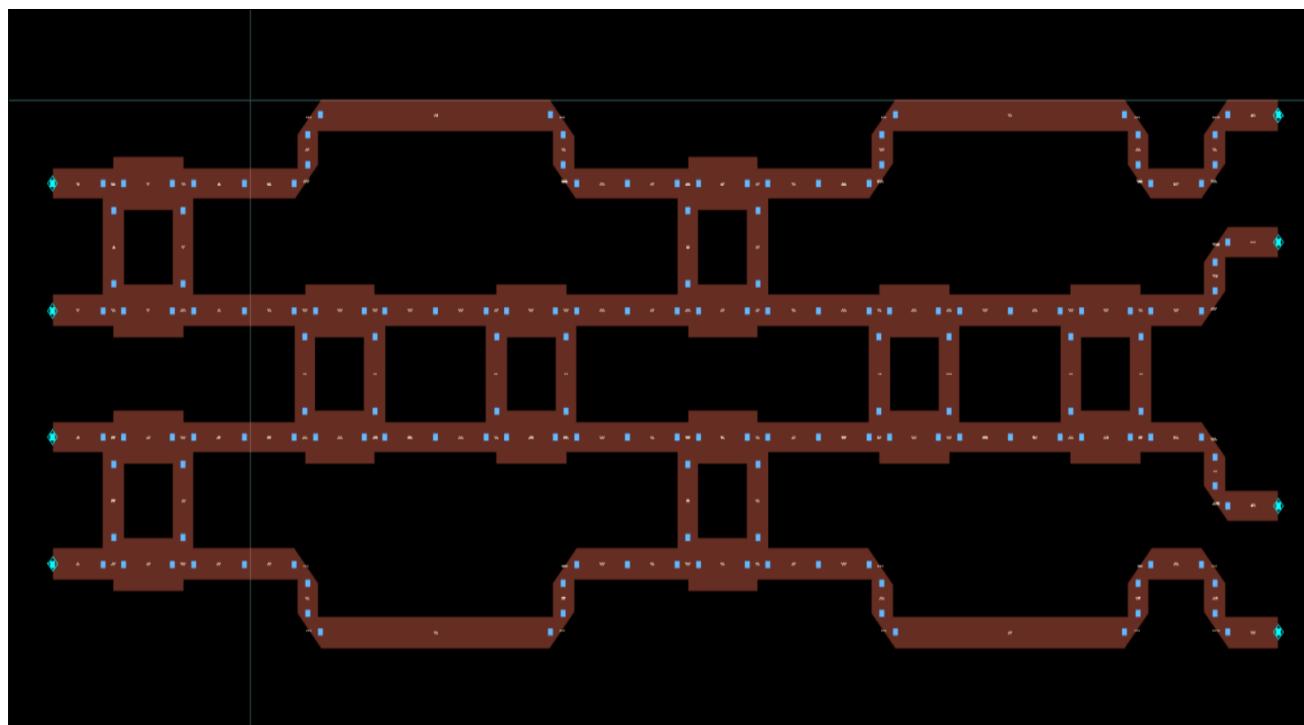


Fig. 11 : Layout of corrected design of the Butler Matrix 4×4 using Microstrip Transmission Lines

5.4 EM Simulation Results

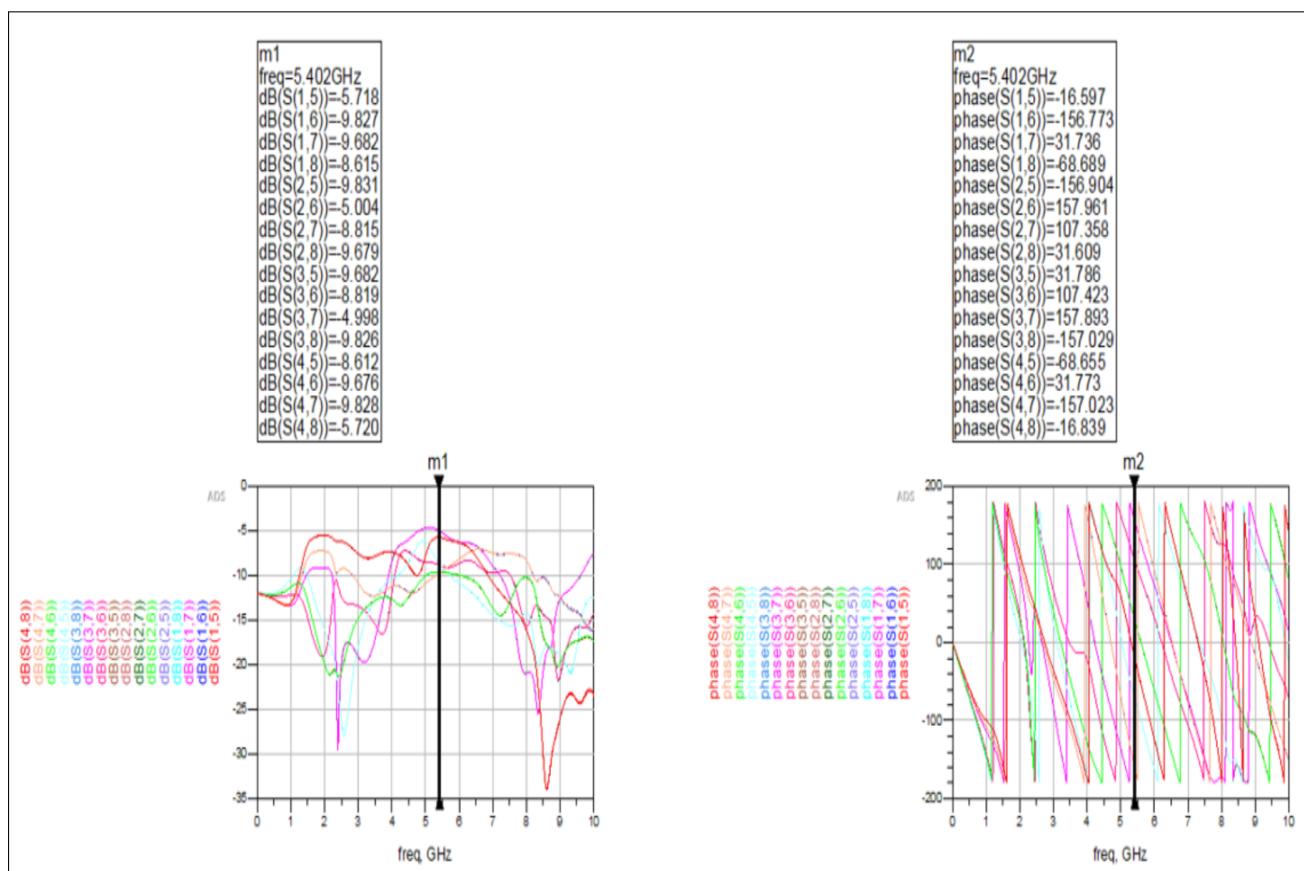


Fig. 12 : EM Simulation Results of corrected design of the Butler Matrix 4×4 using Microstrip Transmission Lines

5.5 Final Cosim Schematic

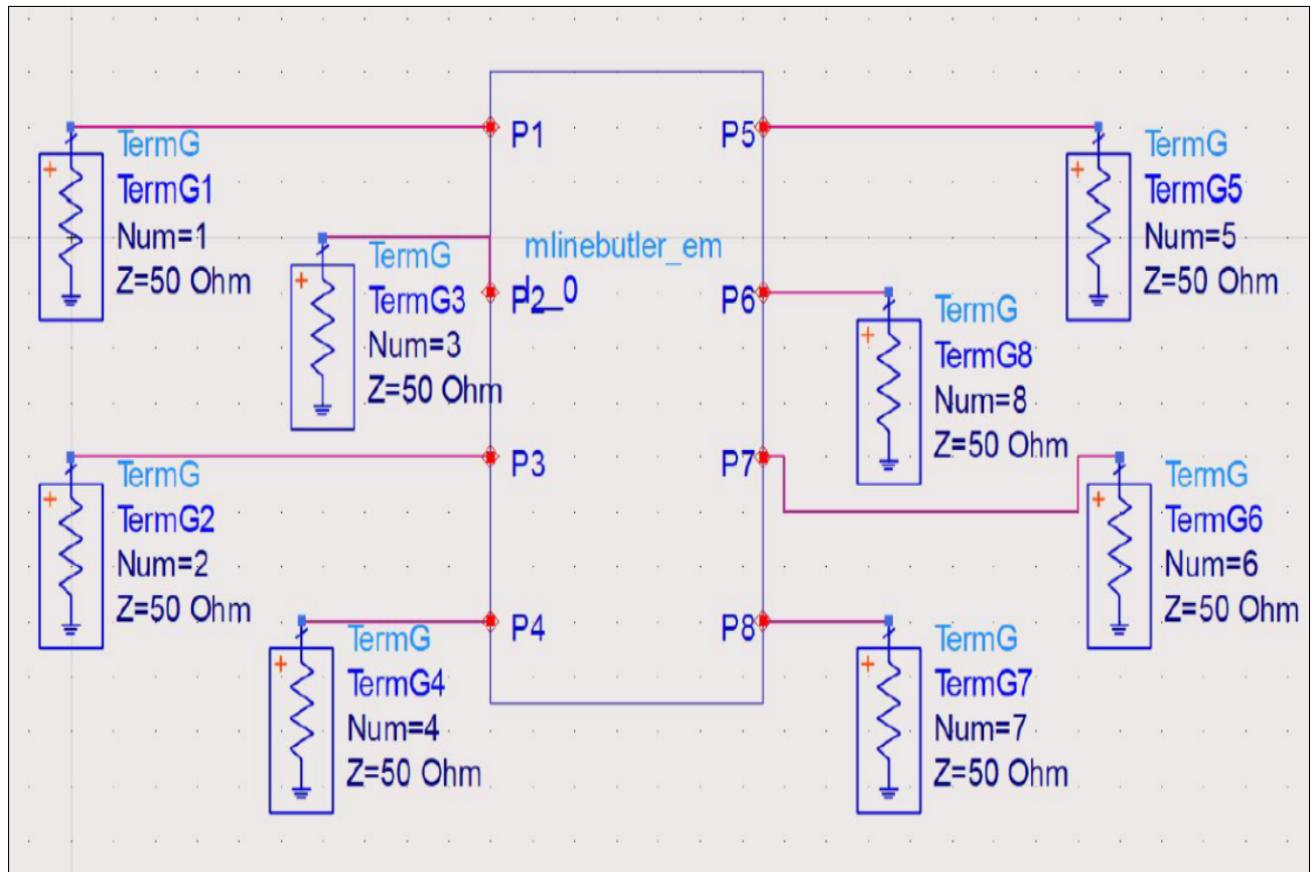


Fig. 13 : Final Cosim Schematic

6. Testing Results

6.1 PCB Design

We built a PCB by designing it in ADS software. It was fabricated in PCB Lab, Department of Electrical Engineering, IIT Bombay using chemical etching. The dimensions of PCB are 19cm×9.5cm. We soldered it in WEL with connectors provided by Integrated Circuits Lab, Department of Electrical Engineering, IIT Bombay

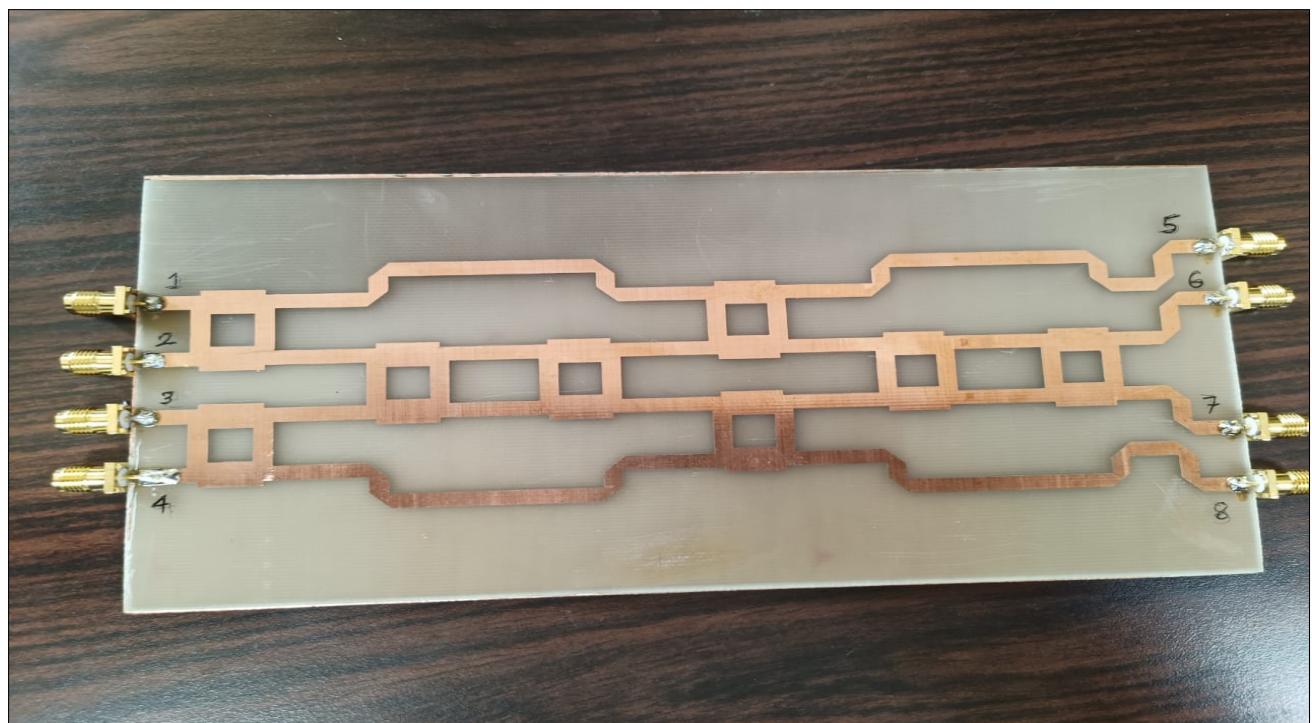


Fig. 14 : PCB Design

6.2 Test Results

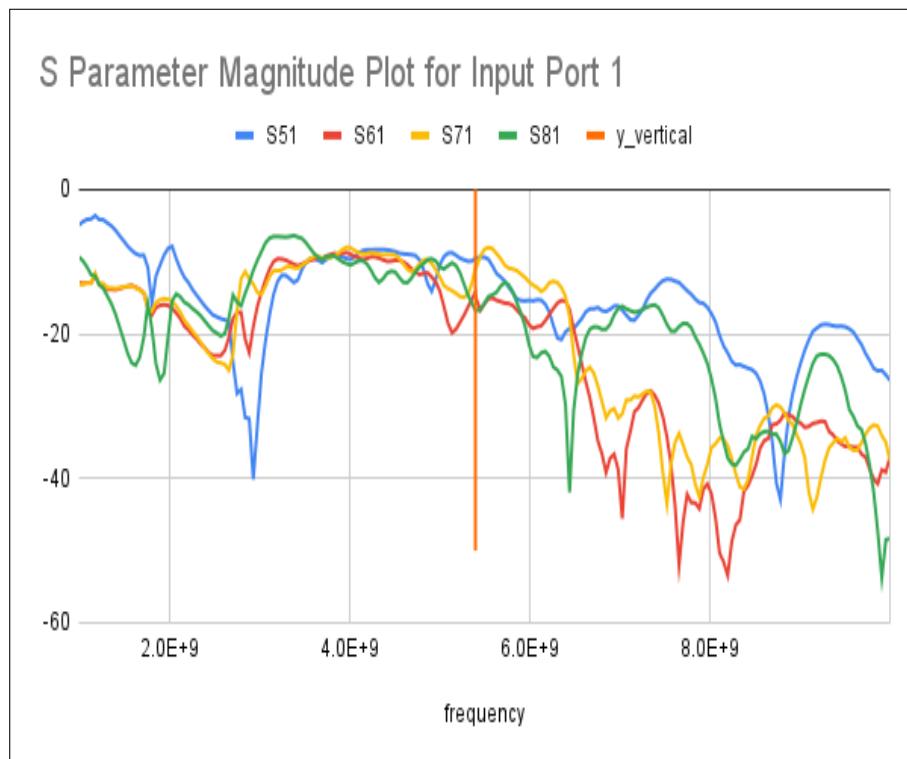


Fig. 14 : Magnitude Plot for Input Port 1

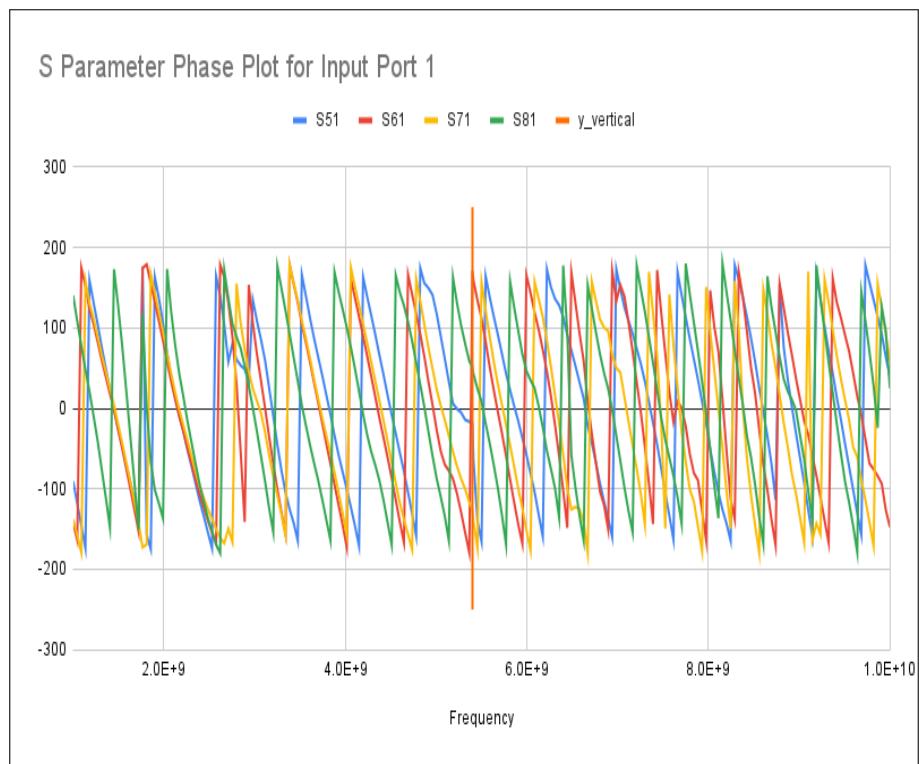


Fig. 15 : Phase Plot for Input Port 1

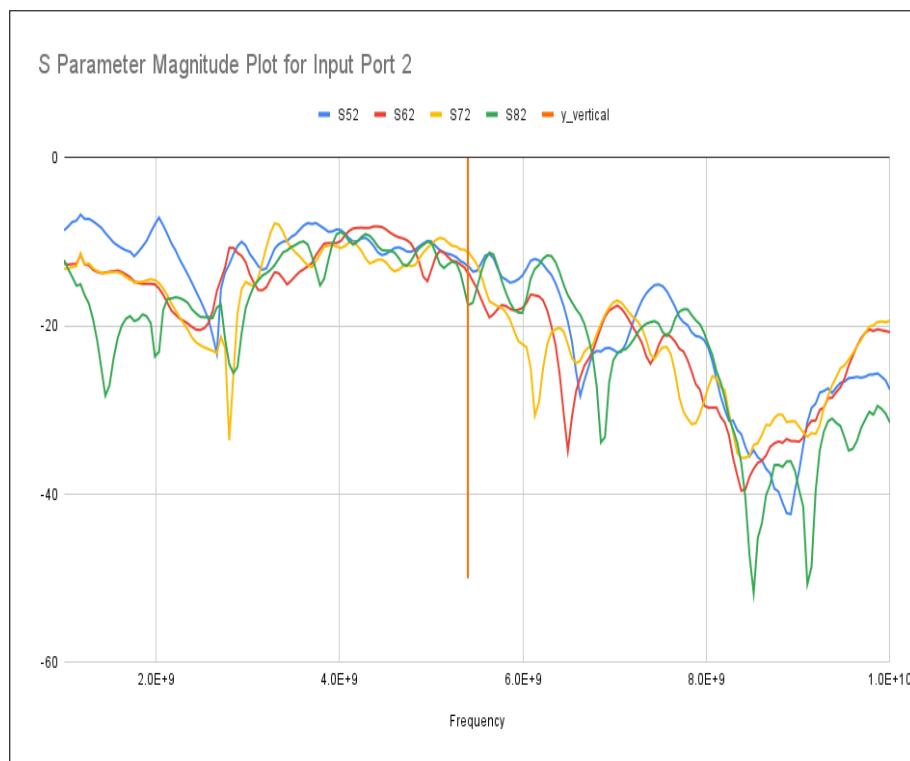


Fig. 16 : Magnitude Plot for Input Port 2

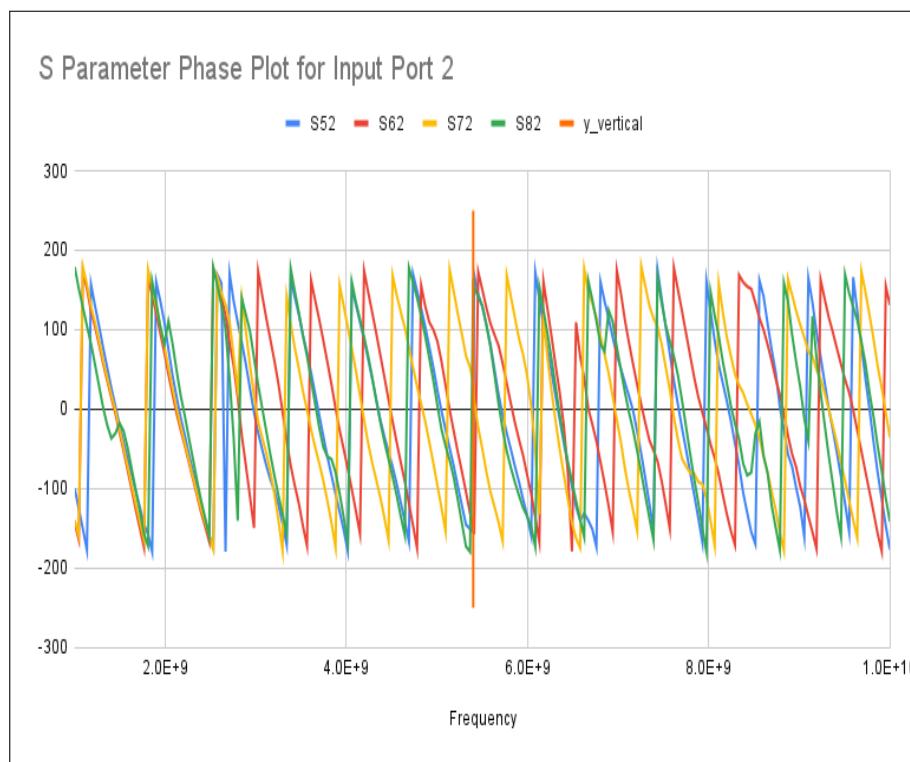


Fig. 17 : Phase Plot for Input Port 2

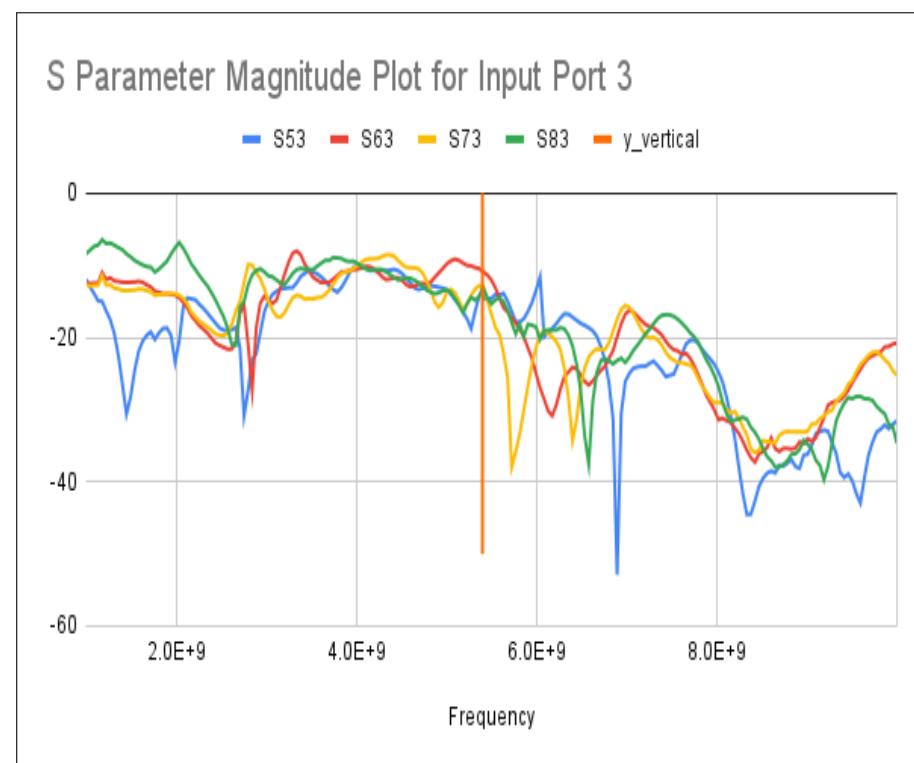


Fig. 18 : Magnitude Plot for Input Port 3

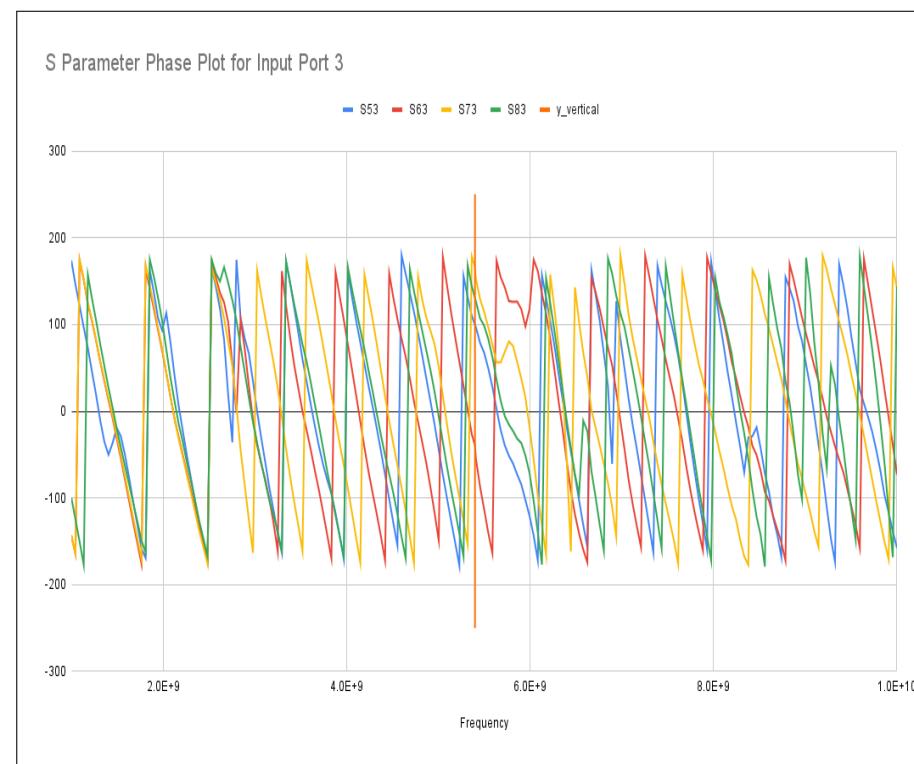


Fig. 19 : Phase Plot for Input Port 3

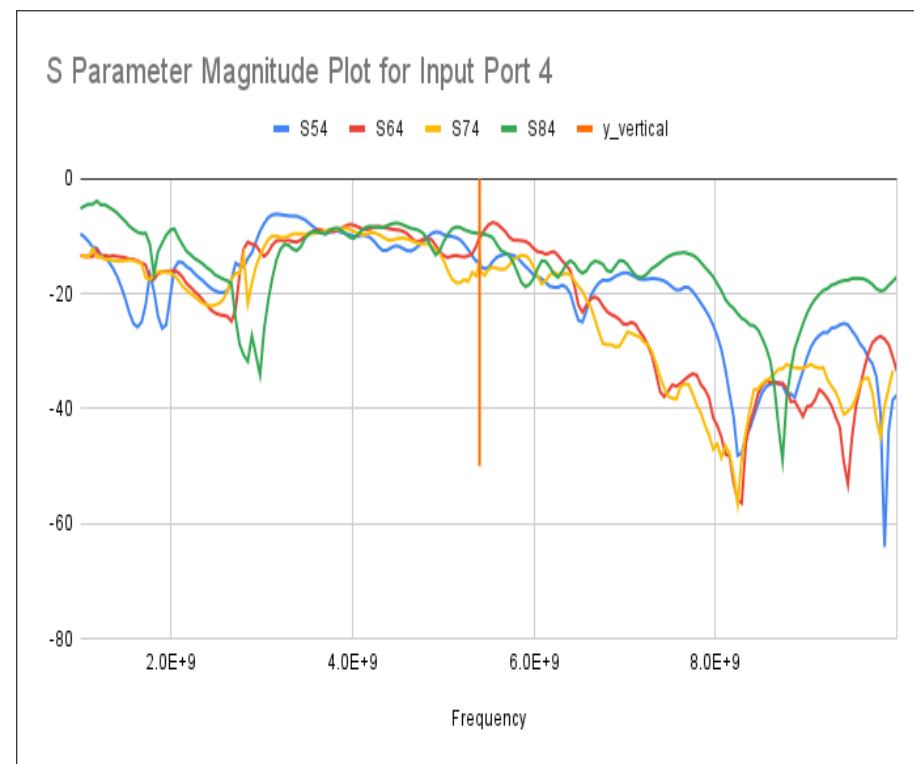


Fig. 20 : Magnitude Plot for Input Port 4

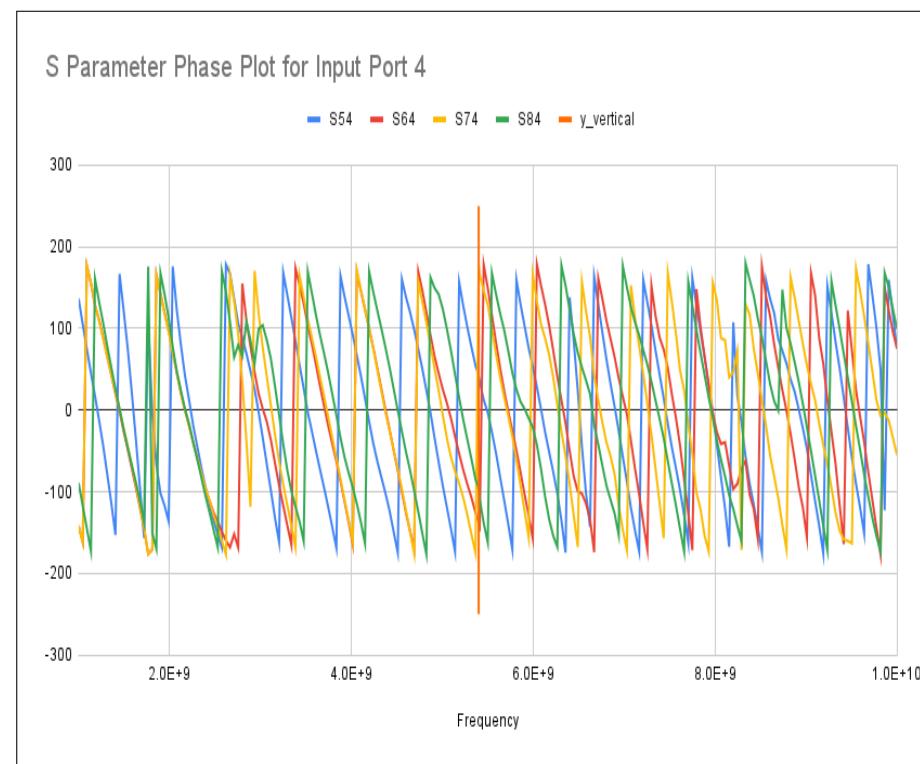


Fig. 21 : Phase Plot for Input Port 4

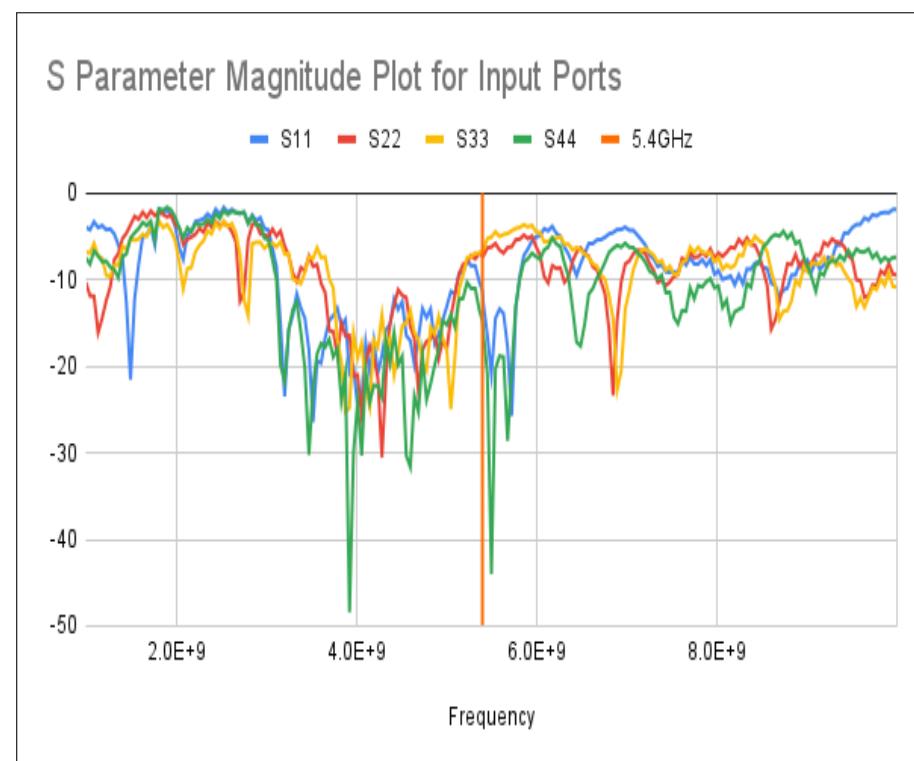


Fig. 22 : Magnitude Plot for Input Ports

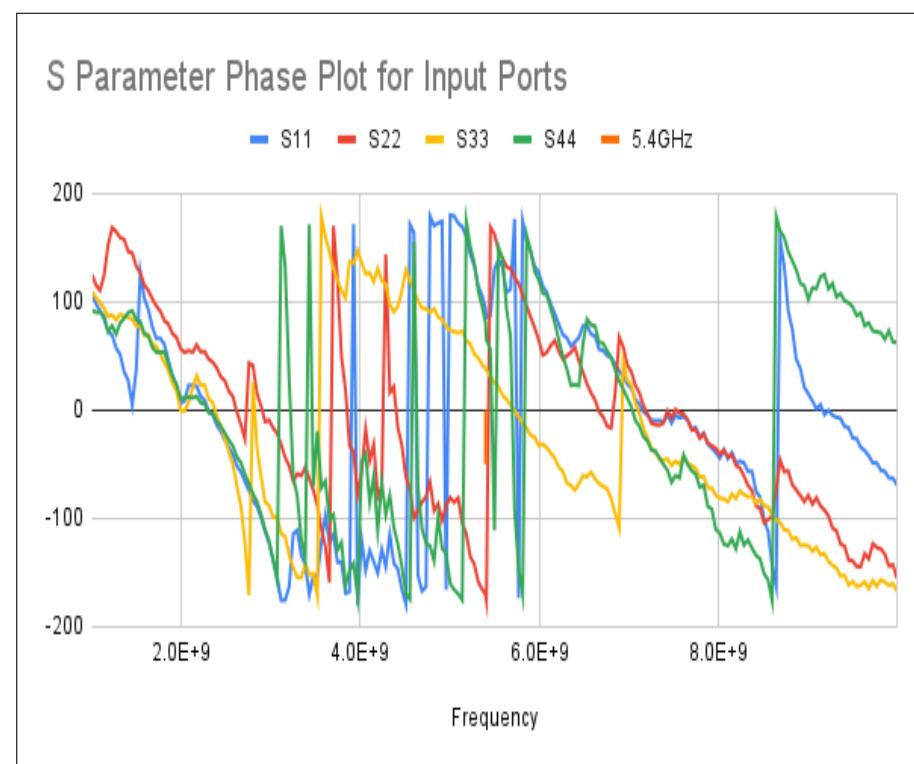


Fig. 23 : Phase Plot for Input Ports

Values of S Parameters measured at operating frequency 5.4GHz are tabulated below

Input Port	S Parameter	Magnitude (in dB)	Phase (in degrees)
Port 1	S_{51}	-9.529913146	-18.4288394
	S_{61}	-14.18488456	171.2849843
	S_{71}	-10.80590679	-125.8310481
	S_{81}	-13.74789855	51.42898599
Port 2	S_{52}	-12.91657455	-154.849067
	S_{62}	-13.71653429	-148.2782401
	S_{72}	-11.248338	34.28130318
	S_{82}	-13.47577044	164.5839108
Port 3	S_{53}	-13.6978377	99.4820281
	S_{63}	-10.8829826	-39.48340283
	S_{73}	-12.92805231	166.4289428
	S_{83}	-13.14814208	130.5839101
Port 4	S_{54}	-13.27040778	42.4723074
	S_{64}	-10.1381972	-137.7238021
	S_{74}	-13.2367354	178.4389148
	S_{84}	-9.555755428	-95.38191303

Table 1 : S Parameters (Output to Input)

S Parameter	Magnitude (in dB)	Phase (in degrees)
S_{11}	-11.2647	93.5729
S_{22}	-7.24398	-170.167
S_{33}	-6.74037	38.6427
S_{44}	-14.7488	80.3359

Table 2 : S Parameters (Input to Input)

7. References

- Denis A. Letavin and Sergey N. Shabunin, "Construction of a 4x4 Butler Microstrip Matrix with Reduced Dimensions", 2020 Ural Symposium on Biomedical Engineering, Radioelectronics and Information Technology (USBEREIT)
- S.Aourik, A.Errkik, J.Zbitou and M.Latrach, "A New Design and Implementation of 4x4 Butler Matrix for Ka Band Applications", URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021
- <https://en.sekorm.com/doc/3468233.html>
- https://en.wikipedia.org/wiki/Butler_matrix#4%C3%974_matrix

