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Design of MMIC phase shifter in Ku Band for Antenna Beam steering applications

Namrata Marigoudar
2410namrata@gmail.com
RV College of Engineering, Bengaluru, Karnataka

Dr. K. Sreelakshmi
hod.tc@rvce.edu.in
RV College of Engineering, Bengaluru, Karnataka

***Abstract*—This Paper presents the 4-bit MMIC Phase shifter at 14 GHz using the Non-Linear demo kit found in the ADS tool. The designed phase shifter have a insertion loss of 4 dB and return losses of 18 dB with phase angles of 22.5, 45, 67.5, 90 deg.**

***Keywords*—** *Monolitic Microwave IC, Ku band, ADS Non-Linear Demo Kit, Phase shifter*

1. INTRODUCTION

The Phased Array antenna have growing applications in satellite communictions because of its ability to steer the beam without moving the antenna which is at stationary position.[1] In this phase shifter design 4-bit phase shifter is designed using high pass filter and low pass filter configuration which provides 0-90 deg phase shift with insertion loss of 4.5 dB and return loss of 18 dB

2. CIRCUIT DESIGN

A. Design of phase shifter

The phase shifter designed is using high pass low pass configuration because lumped componets design in MMIC configuration makes its more compact in the layout design.

The main Objectives of the project are:

- Using ADS demo-kit, design and simulate SPDT switch in MMIC Configuration.
- To design and simulate the phase bits at 22.5/45/67.5/90.0deg in MMIC configuration.
- To Integrate and simulate SPDT and Phase bits to get multi element MMIC Phase shifter

B. Design of SPDT Switch

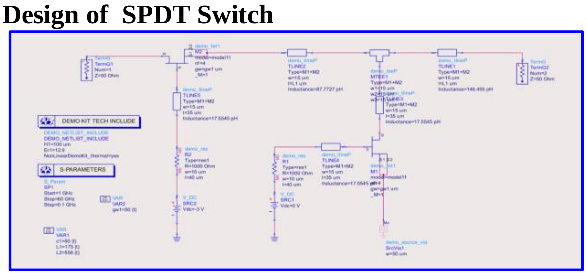

Fig 1(a) Schematic of SPDT switch

The figure 1a represents a SPDT Schematic in ADS window which is mainly designed using series shunt configuration which has better isolation than series switch.

The designed switch is offering the 0.5 dB insertion loss, 19 dB return loss and isolation of 37 dB when the switch is ON.

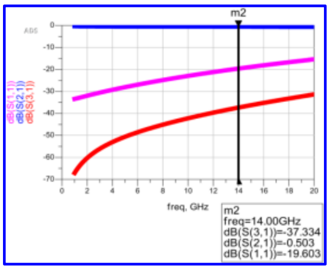

Fig 1(b) Results switch ON

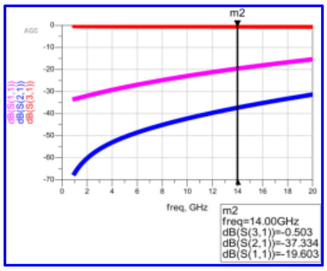

Fig 1(c) Results switch oFF

The figure 1b and 1c represents the results of SPDT switch in ON state at Port 2 and Port 3 respectively. With Port 2 being in ON state, the insertion loss is 0.5 dB, Isolation is 37 dB and Return loss is -19 dB. Similarly, when we switch ON port 3, the insertion loss is at 0.5 dB, Isolation is at 37 dB and Return loss is at -19 dB as shown.

C. Design of low pass and high pass filter

The equations to design filter for the specified angles is for high pass tee

	L1	**C1**
High pass Tee	$L1=zo/w \sin(\Phi)$	$C1=\sin(\Phi)/w\ zo(1-\cos(\Phi))$
Low pass Tee	$L2=zo*(1-\cos(\Phi))/w \sin(\Phi)$	$C2=1/w\ zo \sin(\Phi)$
High Pass Pi	$L1=zo*\sin(\Phi)/w(1-\cos(\Phi))$	$C1=1/wZ0 \sin(\Phi)$
Low pass Pi	$L2=zo*\sin(\Phi)/w$	$C2=(1-\cos(\Phi))/wzo \sin(\Phi)$

D. Design of Phase bit

The LPF and HPF are designed to achieve the required phase angles the calculated formula can be used for ideal elements however once after the replacing with PDK components the values are needs to be optimized. In LPF the series Inductors are replaced with transmission lines due to the small inductance offered by Inductors.

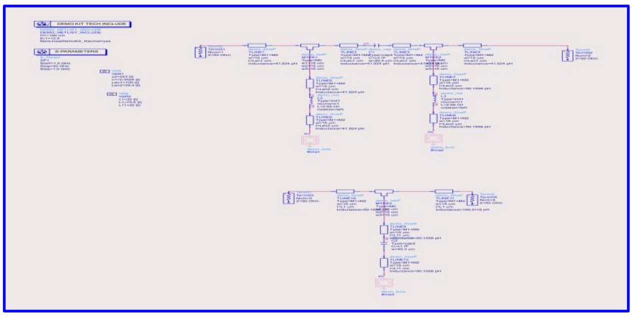

Fig 2 (a) Schematic of LPF and HPF

The same LPF and High pass filters are designed for the other angles as the results are shown below.

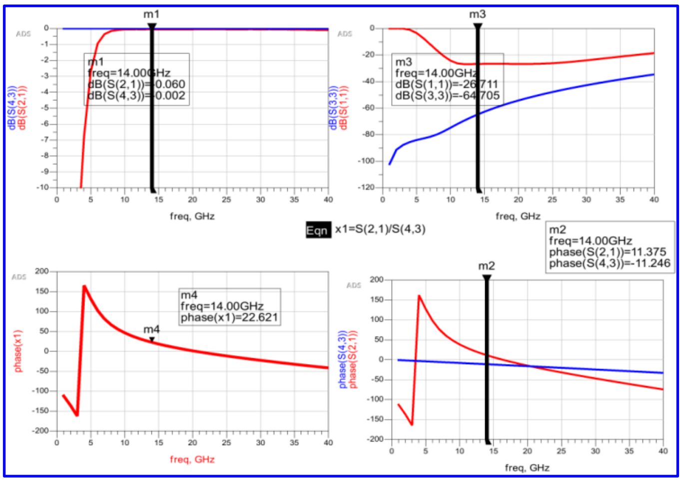

Fig 2 (b) Results to achieve 22.5 deg

The designed LPF and HPF are of angle 11.25 because the LPF angles lags -11.25 and HPF leads in the angle 11.25. the phase difference is 11.25-(-11.25)=22.5 deg. Similarly, LPF and HPF are designed for other angles the simulated results are shown below.

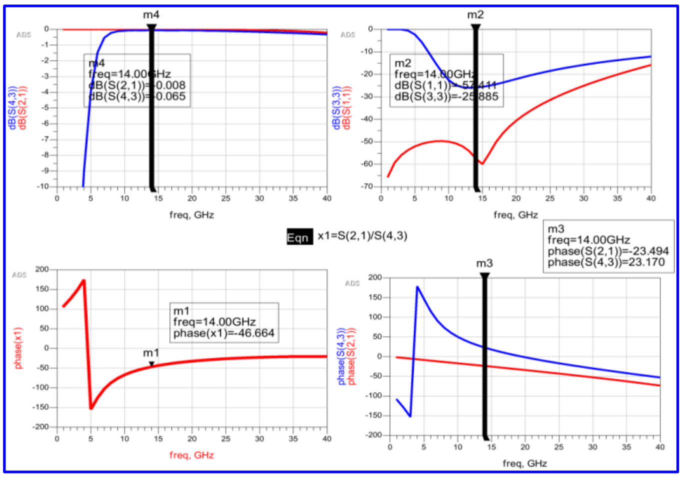

Fig 2 (c) Results to achieve 45 deg

The figure 2 c) represents results of phase bit for 45 deg. The LPF lags by -23 deg phase angle and HPF leads by +23 deg phase angles in this design. Hence the difference between the phases is 46 deg

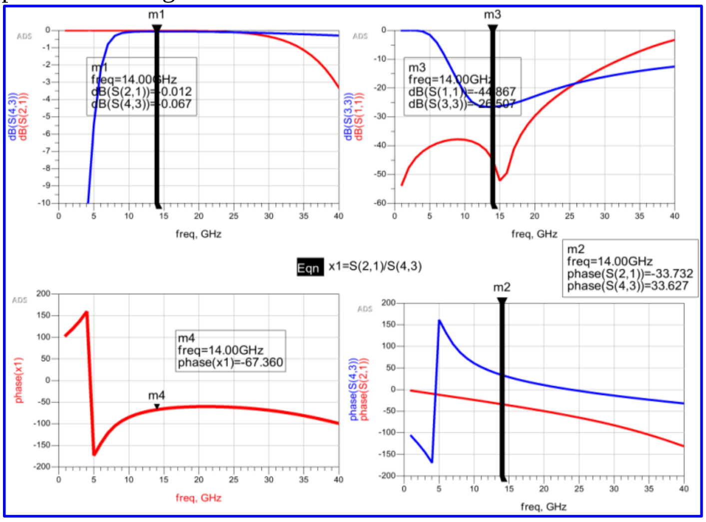

Fig 2 (d) Results to achieve 67.5 deg

The figure 2 d) represents results of phase bit for 67.5 deg. The LPF lags by -33.7 deg phase angle and HPF leads by +33.6 deg phase angles in this design. Hence the difference between the phases is 67.3 deg.

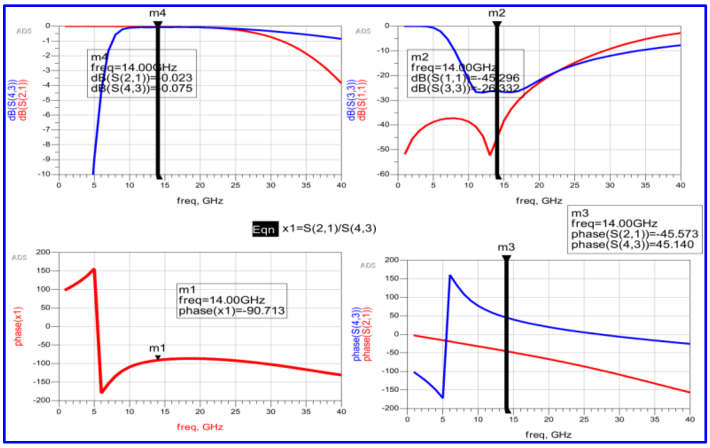

Fig 2 (e) Results to achieve 90 deg

The figure 2 e) represents results of phase bit for 90 deg. The LPF lags by -45 deg phase angle and HPF leads by +45 deg phase angles in this design. Hence the difference between the phases is 90 deg.

E. Phase shifter Design

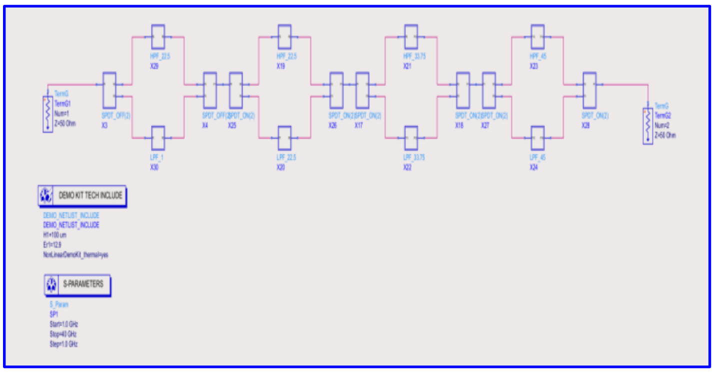

Fig 3 (a) Schematic of Phase shifter

The schematic 3a shows the phase bits integrated with SPDT switch. Each phase bit has two SPDT switch. The designed phase shifter is 4 bit phase shifter.

3. SIMULATED RESULTS

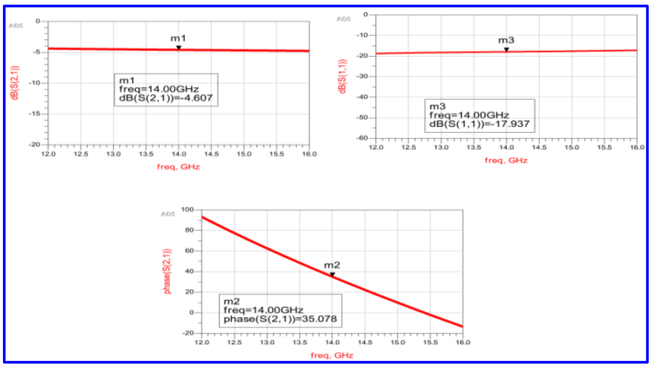

Fig 4 (a) Result achieved at 0 deg

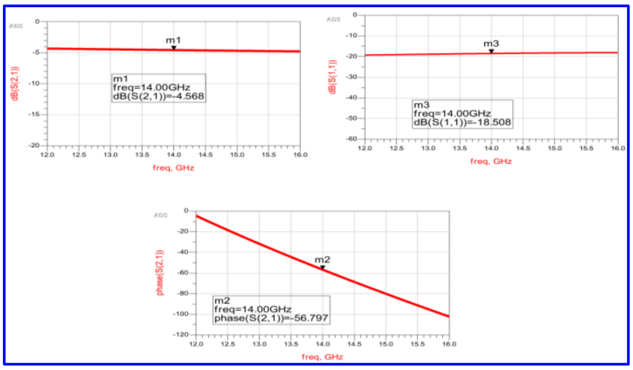

Fig 4 (b) Result achieved at 22.5 deg

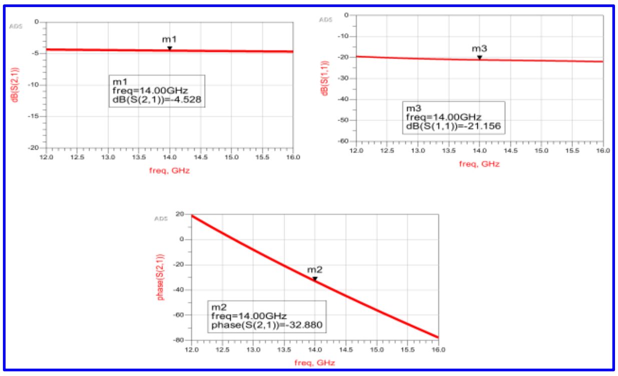

Fig 4 (c) Result achieved at 45 deg

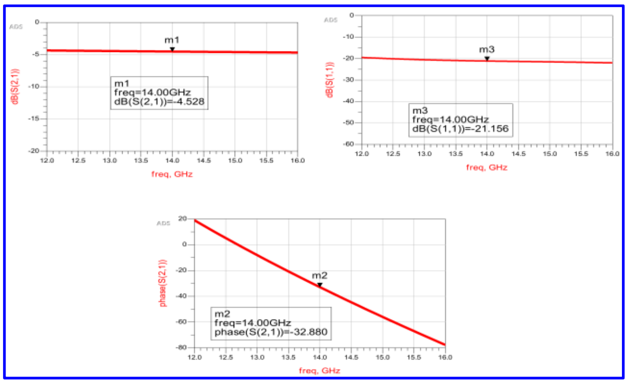

Fig 4 (d) Result achieved at 67.5 deg

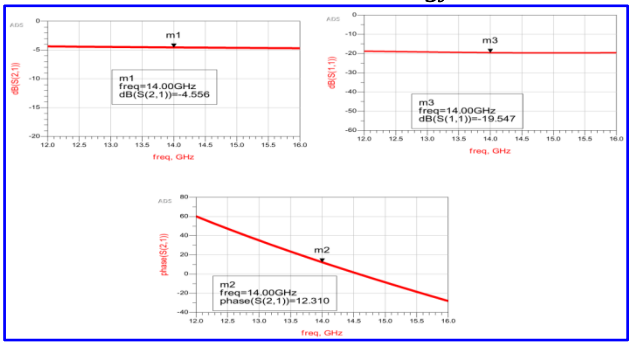

Fig 4 (e) Result achieved at 90 deg

The measured phase shift is compared with the simulated results. It is found that the results are as expected with little phase error. The simulation results with insertion loss of 4.5 dB and return loss of 18 dB.

Bit 0	Bit 1	Bit 2	Bit 3	Expected	Achieved	Error
0	0	0	0	0°	0°	0°
1	1	1	0	22.5°	23°	0.5°
1	1	0	1	45°	47°	2°
1	0	1	1	67.5°	68°	0.5°
0	1	1	1	90°	91°	1°

The Phase shifter Specification achieved

Specification	Value
Insertion loss (dB)	4.5
Return loss (dB)	18
Phase Angles (degree)	23°/45°/67.5°/90°

4. CONCLUSION

In the design of phase shifter the foundry used is from keysight ADS which is available (Non -linear demo kit). MMIC high pass low pass filters configuration phase shifter are used because they are broad band in nature.

One should be careful with some features in the bit network. First the phase bit designed must give the desired phase angles Sufficiently over the required bandwidth. Secondly there should be little amplitude difference among the two states in the phase bit. The designed Phase shifter is giving insertion loss of 4.5 dB and Return loss of 18 dB for the specified phase angles with very less phase error.

5. ACKNOWLEDGMENT

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6. REFERENCES

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