4 bit phase shifter using high-pass/low-pass technique for S-Band RADAR

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ABSTRACT

An attempt has been made to design and simulate 4-bit digital phase shifter at 2.85 GHz using lumped components for S-Band RADAR application. The phase shifter is developed using high pass/low pass technique. PIN diode used to implement Single pole double through switches and Industrial components used as Lumped components. Four sections of phase shifter has been designed, simulated and optimized to achieve targeted specifications. Design technique is demonstrated with 45° phase shifter section with BAP51-02 PIN diode switches in ADS (Advanced Design System) software.

Keyword: - *Phase shifter, High-pass/Low-pass, PIN diodes-Band RADAR*

1. INTRODUCTION

Phase shifter is an important part of phased array antennas, radars and beam forming networks. Phase shifter circuit changes the direction of radiation of the signal passing through it by changing the phase of the signal. Many techniques have been developed to design a phase shifters such as switched line, reflection type, loaded line, lumped Element high pass-low-pass phase Shifter [1].All the phase shifters except the high pass-low-pass phase shifter uses transmission line to provide phase shift in the signal whereas High-pass low-pass phase shifter uses lumped elements like Capacitor ,Inductor. Further high-pass/low-pass phase shifter provides compact size and better bandwidth compared to other type of phase shifters which is useful where size is constraint like phased array antennas used in satellite.

In these phase shifters switches are implemented using either PIN diodes or FET’s but PIN diodes have easier biasing and lower cost. The microwave PIN diode's small physical size compared to a wavelength, high switching speed, and low package parasitic reactance, make it an ideal component for use in miniature, broadband RF signal control circuits. In addition, the PIN diode has the ability to control large RF signal power while using much smaller levels of control power [19]. A PIN diode is a semiconductor device that operates as a variable resistor at RF and Microwave frequencies. A PIN diode is a current controlled device in contrast to a varactor diode which is a voltage controlled devicePIN Diode and the corresponding Equivalent Circuits is shown in Fig.1

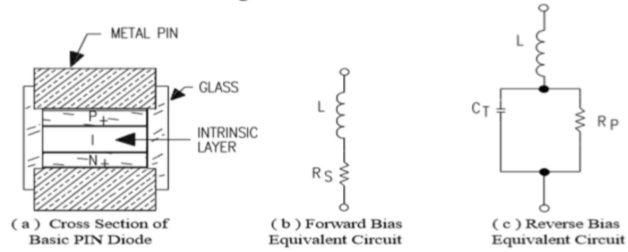


Fig -1 Schematic showing one-bit section of the 4-bit phase shifter [19]

2. DESIGN APPROACH

The phase shifter is designed and simulated using highpass/Low-pass technique at 2.85 GHz for having return loss better than 10 dB, Insertion loss less than 2 dB and Maximum RMS phase error less than 5°.All the simulation and measurements done in Agilent's ADS (Advanced Design System) software 2011.

2.1 Topology: High-pass/Low-pass Filter

This topology was considered suitable for implementation at ISM and S-band frequencies, due to better performance in terms of return loss, insertion loss, and compact size with respect to other phase shifter topologies. Other topologies involving transmission lines for phase shifting resulted in long transmission line lengths at lower GHz frequencies [2].The high-pass filter in π configuration consists of series capacitor and shunt inductors, and the low-pass filter consists of a series inductor and shunt capacitors. The insertion phase undergoes a phase advance in high-pass filter and a phase delay in low-pass network. Phase shift was obtained by switching between the high-pass and low-pass filter. To provide return path for the DC current and for the implementation of PIN diode switches, a large value of DC blocking capacitor can be used in the high-pass filter. Fig. 2 shows the schematic for one complete bit section of the phase shifter

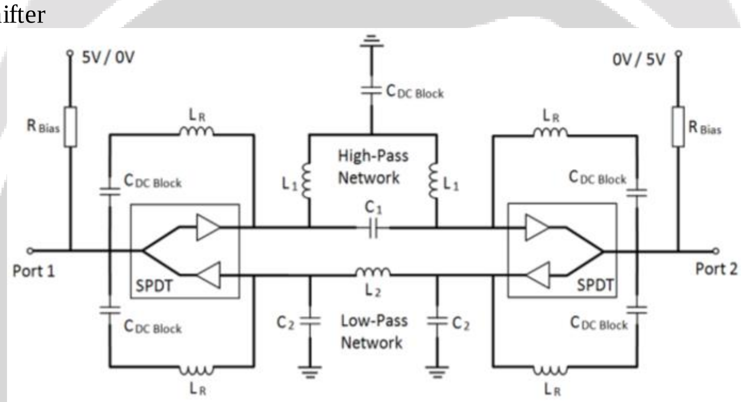


Fig-2 Schematic showing one bit section of the 4-bit phase shifter

At first High-pass/low-pass filters designed with ideal valued lumped component and then they were replaced with Murata components models from the ADS library. The Murata components model was used because they include the parasitic present in the real components. The Murata component series from which the inductors and capacitors were chosen are Inductors: LQG18 and LQW18 series [17] Capacitors:GQM18 series and GRM18 series(Higher values) [18]

Table -1 High-Pass/Low-Pass Component Values

Phase shift	Lumped Element for low pass L1(nH)	C1(pF)	Lumped Element for highPass L2(nH)	C2(pF)
22.5°	0.545	0.222	28.350	5.725
45°	1.069	0.110	14.037	2.291
90°	1.974	0.463	6.741	1.580
180°	2.792	1.117	2.792	1.117

2.2 SPDT switch

Implementation of the Single Pole Double Throw (SPDT) switch is done with PIN diodes.BAP51-02 PIN diode manufactured by NXP has been modeled and simulated using ADS software with murata resonate inductor to overcome the parasitic capacitance provided by PIN BAP51-02 PIN diode[15]. Fig.3 shows the PIN diode modeling of BAP51-02 Switch in ADS software. PIN diode BAP51-02 provides 190fF parasitic capacitance in OFF state as shown in Fig.4 which can be calculated using Y parameter simulation.

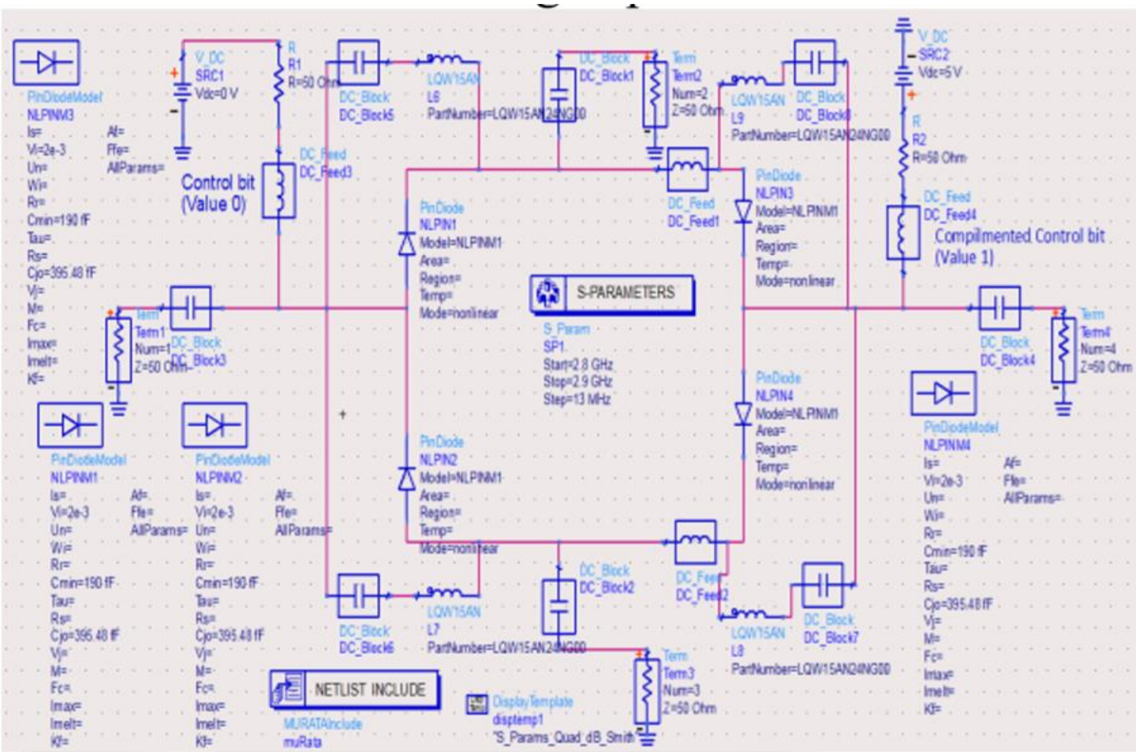
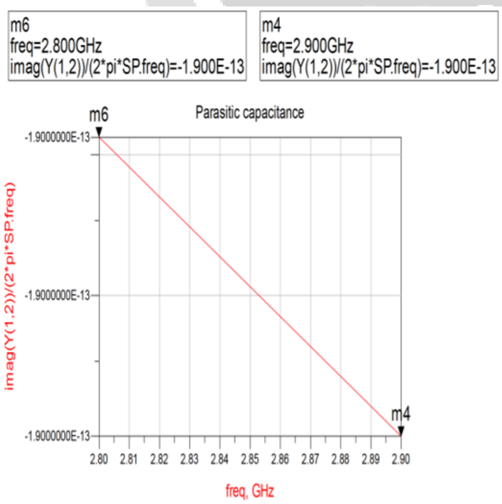


Fig-3 Schematic setup for BAP51_02 switch with murata resonant inductor



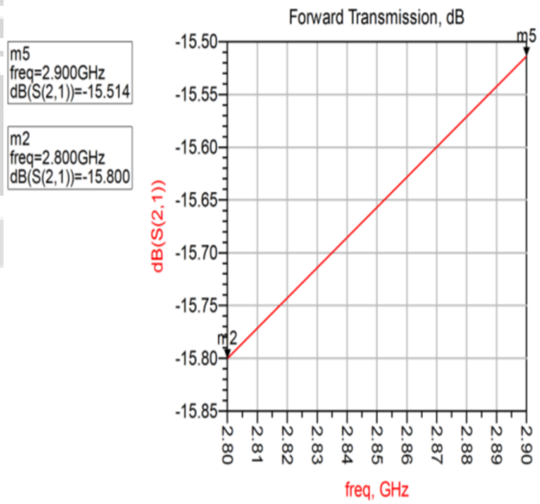
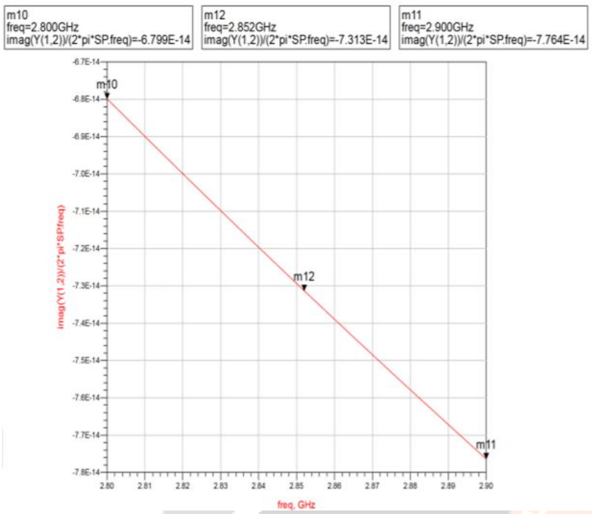


Fig-4 Parasitic capacitance value of BAP51_02 PIN diode in OFF state

Fig-5 Insertion loss of BAP51_02 PIN diode

The insertion loss is -15.650 dB at 2.85 GHz as shown in Fig.5 which degrading isolation of switch in OFF state.LQW15 series murata Inductor of 24nH is selected as resonate inductor to improve isolation of switch in OFF state.



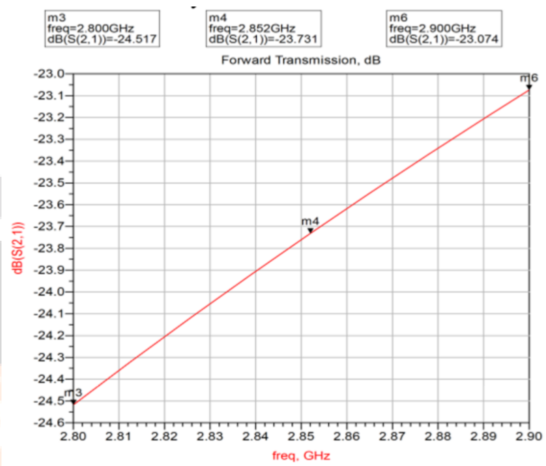


Fig-6 Reduction in parasitic capacitance **Fig-7 Improved Insertion loss of BAP51-02 PIN diode**

Fig.7 shows that Insertion loss of BAP51-02 Increased to -23.731 dB in OFF state which improve the isolation of switch for better switching operation

3. PHASE SHIFTER DESIGN

For demonstration purpose a 45° Phase shifter is designed and simulated using ADS software

The complete Phase shifter circuit with Murata High-pass/Low-pass filter and BAP51_02 Switch is shown in Fig.8.

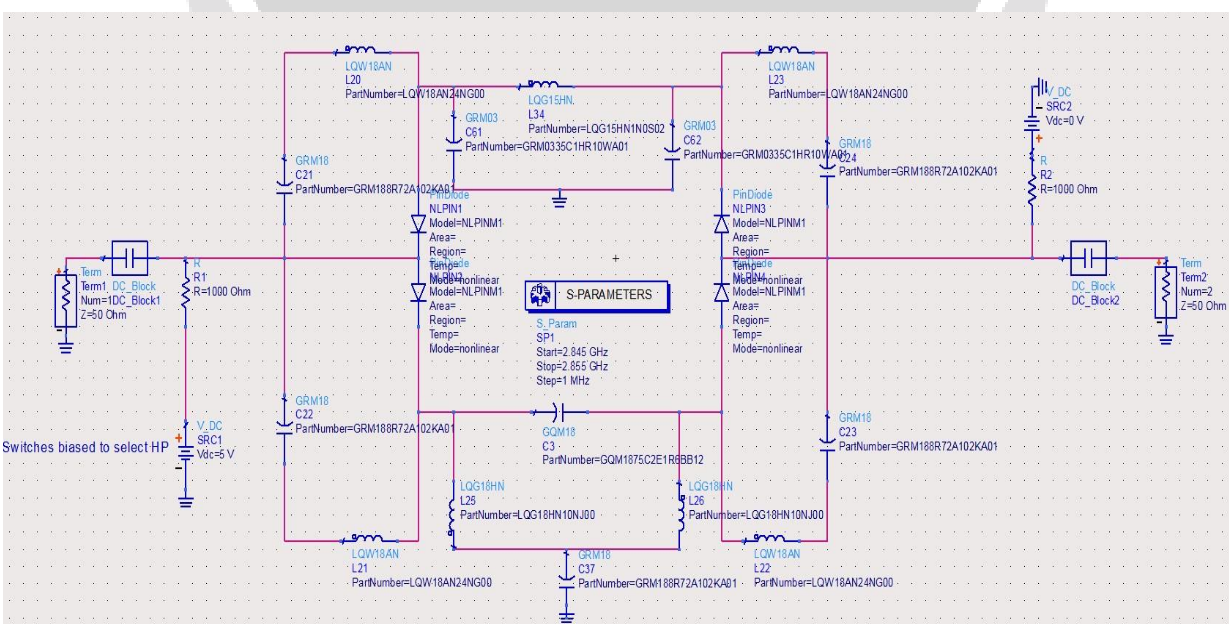


Fig-8 Schematic setup with BAP51_02 switches and HighPass/LowPass Filters biased to select LP filter

In schematic set up BAP51-02 PIN diode switches are biased in such a way that a signal is routed through high pass network which is terminated with Term 1 and Term 2 as shown in figure 8.

Similarly by applying complementary biasing to switch, signal is routed through low pass network which is terminated with Term 3 and Term 4.

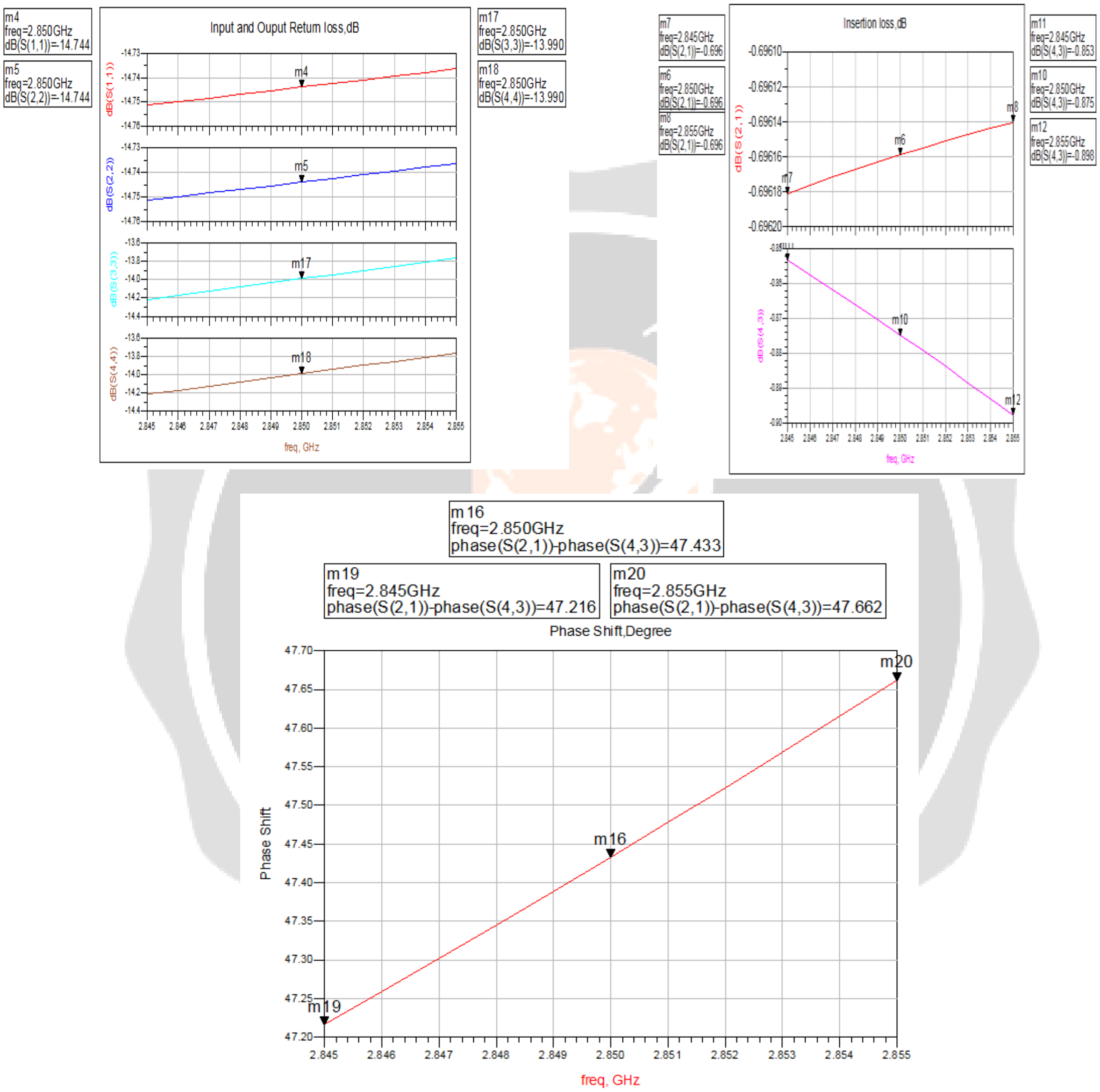


Fig-9 S parameter Response of 45° phase shifter circuit

The remaining three phase shift section i.e 22.5°,90°,180° have S-parameter responses as shown in following figures.

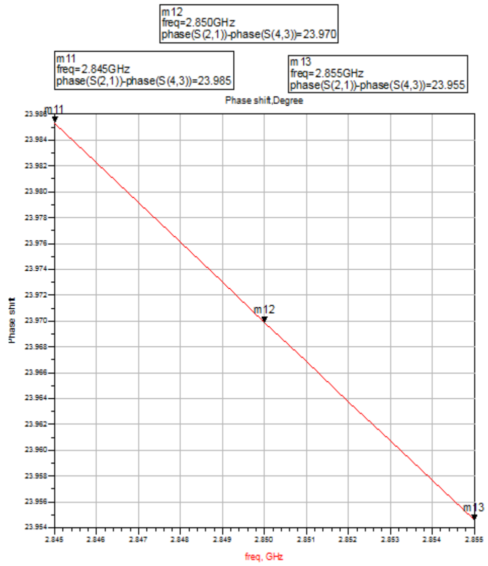


Fig-10 Phase response of 22.5° phase shifter

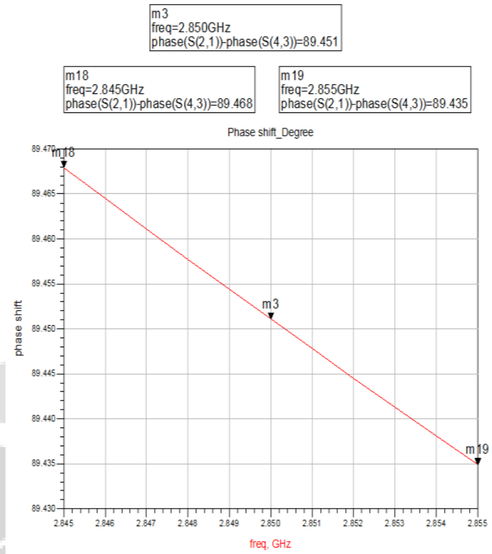


Fig-11 Phase response of 90° phase shifter

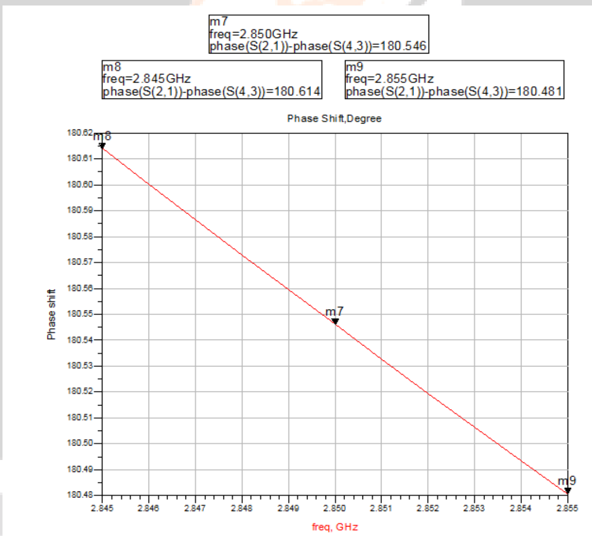


Fig-12 Phase response of 180° phase shifter

4. CONCLUSIONS

Four Sections of phase shifter has been designed, simulated and optimized using high pass/Low pass technique at 2.85 GHz. The return loss is better than 10 dB, Insertion loss is less than 2 dB with maximum variation of Insertion loss is less than 1 dB over the bandwidth. Maximum phase error is less than 3° which share a well agreement with defined specifications of the phase shifter.

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