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Design of a 4 bit MEMS Switched Line Phase Shifter for Phased Array Antenna

T. Pavithra[1], M. Poornalakshmi[2], S. Jeya lakshmi[3] and S. Jeya chitra[4]
[1, 3, 4]PG Scholar, Department of ECE, Sri Vidya College of Engineering and Technology, Virudhunagar, India
[2]Associate Professor, Department of ECE, Sri Vidya College of Engineering and Technology, Virudhunagar, india

***Abstract*— Phase shifters are considering as the most vital subsystem for an antenna in any transceivers or radars. This paper presents a design of 4-bit MEMS switched-line phase shifter, which is calmed by MEMS SP4T switches and micro strip transmission lines is used for an phased array antenna. The Switched-line Phase Shifter is one of the type of Phase Shifter based on the pin diode and metal-contact SPDT RF MEMS switches. The losses are determined in MEMS switched line phase shifter .The SP4T switch is used to switch two different signal pathways of reference phase signal pathway and delayed phase signal pathway. In MEMS switched line phase shifter the SP4T switch consists of four contact type RF MEMS switches with cantilever beam movable contact structure. The performance of these models is simulated by the ADS software. The simulation results show that 4 bit MEMS switched line phase shifter of the return loss and insertion loss of SP4T switch are - 49dB and -0.17 dB, at the center frequency of 10GHz.**

***Index Terms*— SPDT, SP4T switch, MEMS switched line phase shifter.**

I. INTRODUCTION

The phase shifter is an two port device whose basic function to provide a change in the phase RF signal with negligible attenuation. Phase shifter is used to adjust the phase of the wave, is widely used in phased array antennas .The Switched-Line phase shifter is straightforward method because it uses the simple time delay difference between two direct paths to provide desired phase shift. The switching elements are mechanical switches (or relays), PIN diodes, Field Effect Transistors or micro electromechanical systems (MEMS).[1-5].

The propose of a 3-bit digital phase-shifter based on the (DMTL) technique, constituted with 28 RF MEMS shunt switches by loading the CPW transmission line with RF MEMS shunt switches. The DMTL phase shifter is optimized to work between c-to Ku- band of frequencies and it is used for the phased array antenna,[6,7] compare with the MEMS switched line phase shifter It needs of 28 switches have been placed to make a complete structure of 3-bit phase shifter.

Switched-line Phase Shifter is one of the type of Phase Shifter based on the SPDT switch and diodes and their phase shift corresponds to the length difference between two switched transmission line. The basic switched-line phase shifter is the most straightforward type using two, Single Pole Double Throw (SPDT) switches to route the signal flow between one of two transmission lines of different length.[8] The desire of the switched line phase shifter based on PIN diodes is to integrate it into a micro strip transmission line dedicated to X band applications.[9-10].

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In this paper, we design a 4-bit MEMS phase shifter, which works in X-band and used for the phased array antennas . In MEMS SP4T switch is used to switch two different signal pathways reference phase signal and delayed phase signal pathways Compared with the switch-line phase shifter[9,11] ,In MEMS switched line phase shifter composed of sp4t switch design the number of switch to achieve the phase shift is reduced by a half .Due to four movable contact MEMS switch so it achieve a whole 16 different phase shifter in this design So it helps to reduce the power consumption of the phase shifter and also is used reduces thelosses. This designs have been simulated using Advanced Design System software (ADS).[11-12].

A. Transmission Line

Micro strip transmission lines consists of a conductive strip of width "W" and thickness "t" and a wider ground plane, separated by a dielectric layer of thickness. It uses an FR-4 substrate that carries permittivity of 4.8. The width and height should be in the dimension of of 1.8mm and 1mm . The W/H ratio is more than 1 for this design and calculation.

II. DMTL PHASE SHIFTER

The design of DMTL phase shifter by using periodic placement of MEMS shunt switch on CPW is known as DMTL phase shifter**.** DMTL phase shifter is designed by loading CPW transmission line periodically using MEMS shunt switch**..**The design of DMTL phase shifter using CPW is used to achieve reduced size and better RF performance but, regrettably as frequency increases CPW suffers from losses caused by air-dielectric material discontinuity.

As compare with DMTL phase shifter the MEMS switched line phase shifter provides low losses so prefer with the MEMS switched line phase shifter . The 3 –bit DMTL phase shifter exhibit only 0/360º. A 3-bit RF MEMS phase shifter is presented the RF performances with - 38.196 db as the reflection loss and -0.53db as an insertion loss of 360° phase shift at 15 GHZ.

III. SWITCHED LINE PHASE SHIFTER

The switched-line phase shifter is reliant only on the length of the lines. One of the two lines is labeled as a reference line, and the delay line. The switched-line phase shifter is working based on different signal electric length which resolves the absolute phase shift of all signal paths. The switched line phase shifter composed based on SPDT switch and pin diode,The switched-line phase shifter was built on FR-4 substrate with a relative permittivity of 4.8.

Switched line phase shifters based on Pin diodes are used for switching the signal between two transmission lines to achieve the desired phase shifter. The pin diode has the difference of playing the role of a switch with two in reverse bias the signal passes and in forward bias is reflected.

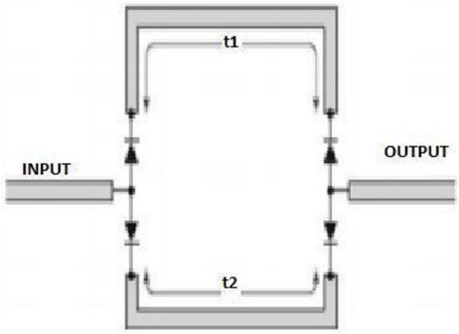

Fig 1:Basic schematic switched line phase based on pin diodes

As 4 PIN diodes used 2 each for an SPDT switch and corresponding DC blocking capacitors is connected between an transmission lines. and gives as an reduced losses with comparison of SPDT switch. The SPST architecture is extensive to make the proposed system , the switch has two output branches in which four diodes are connected in parallel to make an switched line phase shifter. The differential phase shift between the two paths is expressed by

$$\Phi = \beta (L2 - L1)$$

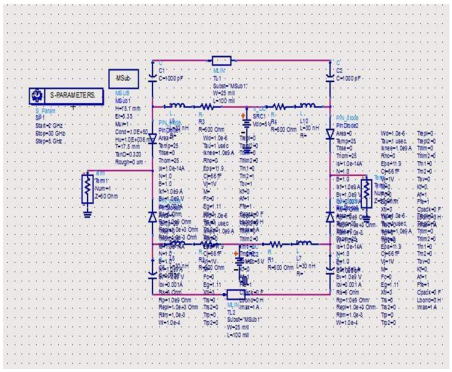

Fig 2 : Switched line phased shifter based on pin diode

The Switched line phase shifter based on SPDT(single pole double throw) switch consists of a power splitter and two pairs of capacitive MEMS shunt switches and it done a variety of functions which is the most straight forward type using two, Single Pole Double Throw (SPDT) switches to route the signal flow between one of two transmission lines of different length the SPDT are more compact in size.

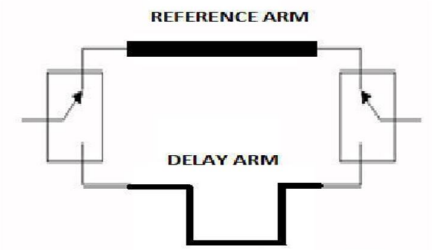

Fig 3: Basic schematic switched line phase shifter based on SPDT switch

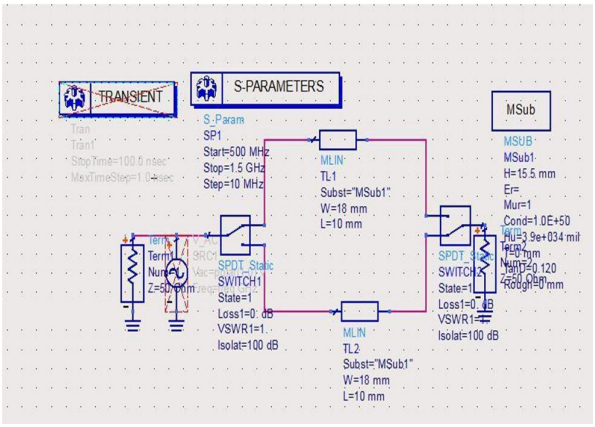

Fig 4 :Switched line phase shifter based on SPDT switch in ADS

IV. PROPOSED SYSTEM

A. 4 bit MEMS switches line phase shifter

Consider an 4-bit MEMS switched-line phase shifter is composed by MEMS SP4T switches and micro strip transmission lines The basic SPDT is the basic circuit that will allow us to pass the SP4T switch and is extended

to make SP4T switch,. In MEMS SP4Tswitch consists of four contact type RF MEMS switches with cantilever beam movable contact structure. The basic schematic sp4t switch are shown in below figure.

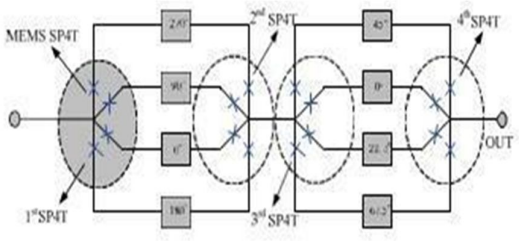

Fig 5:Basic Schematic diagram of the 4-bitMEMS switched-line phase shifter based on SP4T switch

Four MEMS SP4T switches is composed by the coarse adjustment phase (180°, 90°, 270° and 0° reference phase)and and fine adjustment phase (45°, 22.5°, 67.5° and 0° reference phase). This two level of phase shifter uses two SP4T switches to achieve the strobe of 4 different phases the whole 4-bit switch-line phase shifter needs four SP4T switches to connect with the transmission lines.. The 4-bit MEMS switch-line phase shifter totally needs 16 contact type RF MEMS switches.

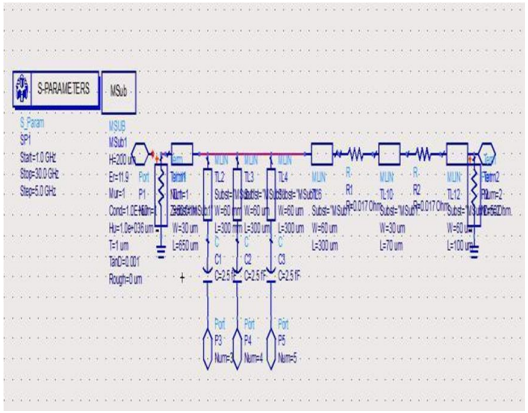

Fig 6 : Equivalent circuit of the SP4T Switch

ADS software is used to stimulate the equivalent circuit model of SP4T switch is shown in above figure. In this circuit the vertical distance between the contact metal of the cantilever beam MEMS switch and transmission line is 3µm, disconnect distance of the transmission line is 70µm, and calculated value of the capacitance is about 2.5fF and resistance is about0.017fi.

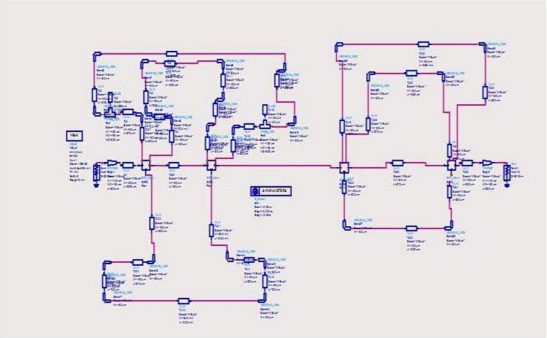

Fig 7 :Equivalent circuit model of the 4-bitMEMS switched-line phase shifter

The ADS software is to simulation equivalent circuit model of MEMS switch-line phase shifter. It includes a MSUB tool to set the phase shifter of fr4 substrate parameters that include of dielectric constant £r=11.9, substrate thickness H= 200µm, the transmission line thickness of the T= 1µm.

The S parameters for each network can also be obtained by,

$$S_{11} = \frac{[Y_o + \frac{1-\omega L}{j\omega^2 LC}]^2 + [\frac{1}{\omega L}]^2}{[Y_o + \frac{1-\omega L}{j\omega^2 LC}]^2 - [\frac{1}{\omega L}]^2}$$

$$S_{21} = \frac{2\omega LCY_o}{C(1+\omega^2 L^2 Y_o) + jL(1-\omega)}$$

The phase shift step is 360°/16=22.5°,it gets 16 different phase shift are 0°,22.5°,45°,67.5°,90°,112.5°,135°,157.5°,180°,2 02.5°,225°, 247.5°, 270°, 292.5°, 315° and 337.5°. It works as follows the amount of phase shift need to be45°,first use the coarse adjustment phase 1st and 2nd SP4T switch, turn on the two RF MEMS switches of delayed phase signal pathway, which correspond to the phase shift is 0°; then, use the fine adjustment phase 3rd and 4th SP4T switch, turn on the two RF MEMS switches of delayed phase signal pathway, which correspond to the phase shift is 45°. At this time, there are four MEMS switches in working state. Similarly with the same procedure it produce an phase shift of 0, 180 and 360 .°

V. Result and Discussion

A 3-bit RF MEMS phase shifter is presented the RF performance with -38.196db as the reflection loss and -0.53db as an insertion loss of 360° phase shift at 15 GHZ are give in below figure.

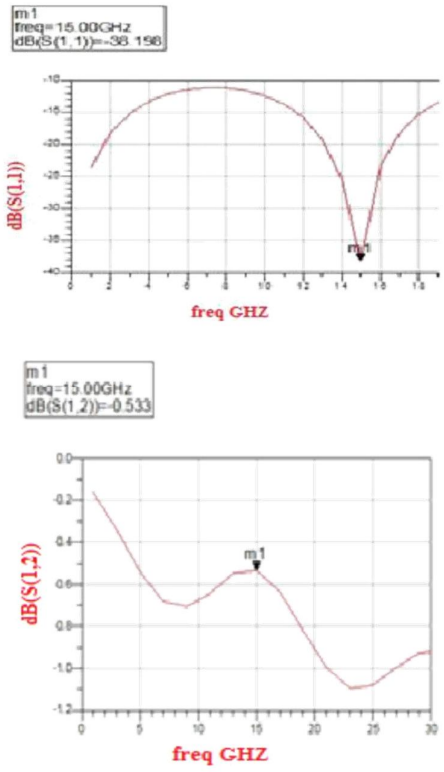

Fig 8 :Return and insertion losses for DMTL phase shifter

The Design simulated using ADS tool Return loss of -19.94dB and insertion loss less than 1 dB for the better result that we got -0.7dB.are shown in below fig

Fig 9: Return and insertion losses based on pin diode switched line phase shifter

The SPDT switched are simulated in ads gives shown in below figure a quite linear curve it delivering good return loss more than 30 dB and good insertion loss maintained at less than 1 Db are

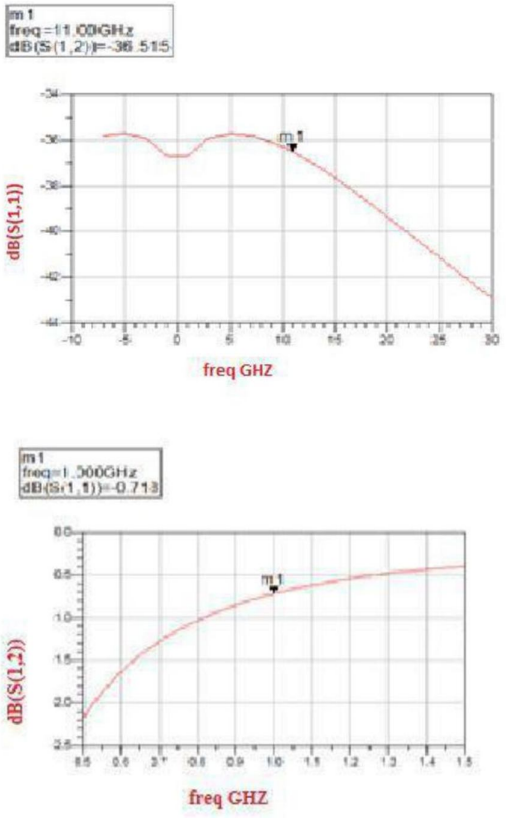

Fig 10 :Return and insertion losses of SPDT switch

When to simulate an equivalent circuit SP4T switch use the ADS software as we get result of at the center frequency of10GHz, it gets a return and insertion loss of SP4Tswitch is about -49dB, 0.18dB are given in below figure.

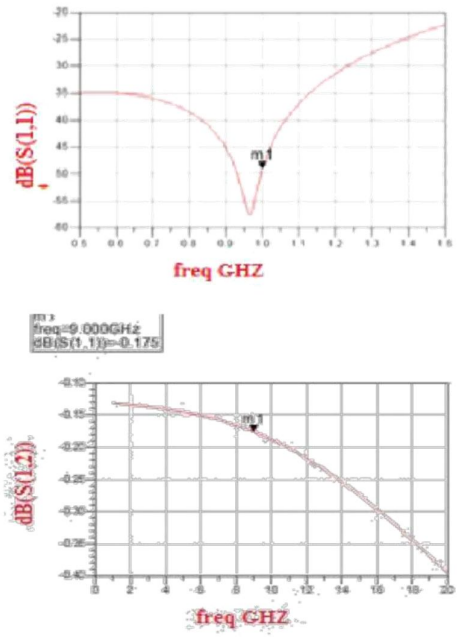

Fig 10 : Return and insertion loss for the equivalent circuit of the MEMS switched line phase shifter

The phase shift 360°/16=22.5° it gets 16 different phase shift

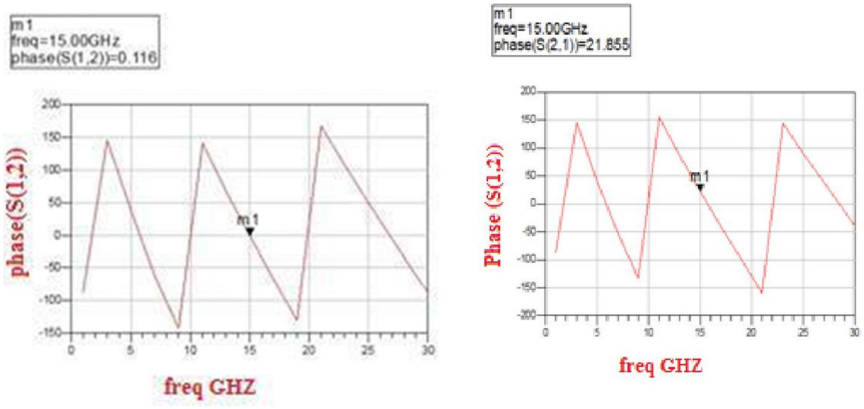

Fig 11: phase characteristics of 21.5,0/360°

VI. Conclusion

Design a switched-line phase shifter based on SPDT switch and pin diode .The design simulated by using Agilent's ADS tool was gained and technically understood the methods and the results based on S parameters are

summarized and got an return loss and insertion loss of - 19.94 dB - ,0.700 dB. The 4-bit MEMS switched line phase shifter is designed in order to shift the phase of degrees from 0° to 360°.The Simulation results show that we may have worked in the architecture of SP4T switch .Through which the sp4t switch simulation by using the ADS software, we know that, at the center frequency of 10GHz, return loss and insertion loss of SP4Tswitchisabout-49dB, 0.18 dB. SP4T switch as the phase selector switch, which is combined by contact type RF MEMS switches with cantilever beam movable contact structure; The advantages of low power consumption and the number of switch to achieve the phase shift is reduced by a half.

TABLE I : COMPARISION RESULTS

DESIGN	FREQUENCY	RETURN LOSS	INSERTION LOSS	PHASE SHIFT
I bit DMTL phase shifter	15 GHZ	-34db	-0.5db	0°
3 bit DMTL phase Shifter	15 GHZ	-38db	-0.53db	3600°
Switched line phase shifter based on pin diode	10 GHZ	-19.9db	-0.6db	0-360°
Switched line phase shifter based on SPDT switch	10 GHZ	-36.5db	-07db	0-360°
MEMS switched line phase shifter	10 GHZ	-49db	-0.17db	0-360°

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