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SMALL SIZE AND LOW LOSS RF MEMS PHASE SHIFTER

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ABSTRACT

This paper aims to design a MEMS DMTL type phase shifter by reducing insertion loss and line length with increase in phase shift. The distributed MEMS transmission line phase shifter has been developed using MEMS bridges on coplanar waveguide and Bilateral Interdigital coplanar waveguide. The idea is to add existent capacitances with additional capacitor in parallel. The design utilizes MEMS switches in the DMTL phase shifter to change resonance condition. Phase shift will be produced by adding MEMS Bridge on the CPW. There are 11 bridges placed periodically in the transmission line which can produce more delay producing large phase shift. By varying the height of the bridges, different levels of phase shift can be achieved using MAM capacitor. To reduce size of CPW length and to increase phase shift, BICPW technique has been introduced. By varying the height of the bridges, different levels of phase shift can be achieved, as a result the size and losses are decreased.

Keywords*: MEMS, DMTL, CPW, BiCPW, phase shifter.*

I. INTRODUCTION

Microelectromechanical systems (MEMS) technology makes it easy to fabricate electromechanical and microelectronics component in a single small device ranging from 1 μm to 1 cm. The mechanical sensor and actuators with electronic processors and controllers can be fabricated in a single substrate in an unbroken, wafer-level process flow and integrated in chip level. The integration of MEMS into Radio Frequency (RF) circuits has resulted in systems with superior performance levels and lower manufacturing costs.The phase shifter is a two-port device, whose sole responsibility is to alter an input signal's relative phase according to a control signal. The design of the phase shifter can be as simple as connecting bridges in the coplanar waveguide (CPW). Ideally phase shifters provide low insertion loss, high power handling, instantaneous phase change response, and approximately equal loss in all phase states. Phase shifters are applied in frequency translators, phased arrays, etc.

II. DISTRIBUTED MEMS TRANSMISSION LINE (DMTL)

Distributed techniques have been used as a solution to obtaining very wide band circuits. The idea is based on periodically loading a t-line with transistors, Schottky diodes or passive components such as capacitors or stubs to obtain wide band amplifiers, oscillators, mixers, multipliers and pulse-shaping circuits. The concept is very useful because the parasitic of the discrete device, such as the gate-to-source capacitance of transistors in travelling wave amplifiers or the capacitance of the Schottky diode in nonlinear pulse shaping circuits, are included as part of the distributed model of the transmission line, thereby resulting in wide band operation. Furthermore, distributed circuits often result in a precise analytical model which greatly simplifies the design process.

The Distributed MEMS Transmission Line (DMTL) is composed of a Coplanar Waveguide (CPW) line, as shown in Fig 1 and Fig 2 shows a periodic set of the MEMS Bridge on a CPW line, which can be easily used as the voltage-controlled phase shifter. By using the single analog control voltage to vary the height of the MEMS bridges, the distributed capacitive loading on the t-line, and therefore the propagation characteristics can be varied. This result in analog control of the t-line phase velocity and therefore results in a true-time delay phase shifter. However this implementation suffers from two serious drawback, Mechanical instability of the MEMS bridge under a constant DC bias voltage results in a theoretical usable capacitance ratio of 1.5 and a practical limit of 1.2 – 1.3. Also, the analog design suffers from Brownian noise effect, and from the electrical noise on the bias line which transfers into phase noise at the output of the phase shifter. Fig 3 illustrates the equivalent circuit of unloaded CPW and Fig 4 gives the equivalent circuit for loaded CPW.

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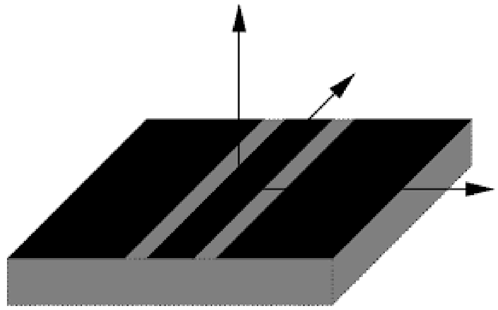

Fig 1: Structure of Coplanar Waveguide

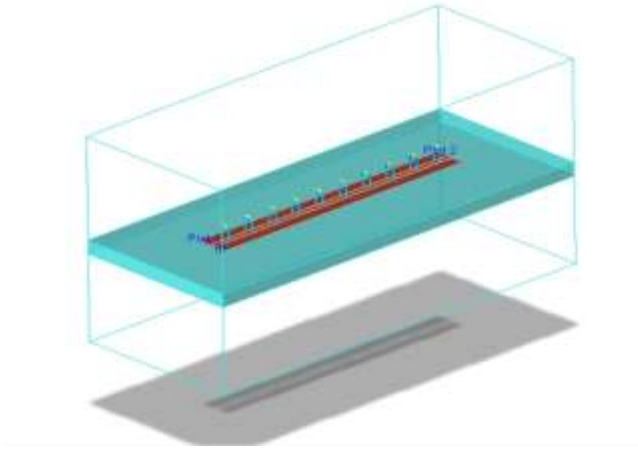

Fig 2: 3D view of DMTL

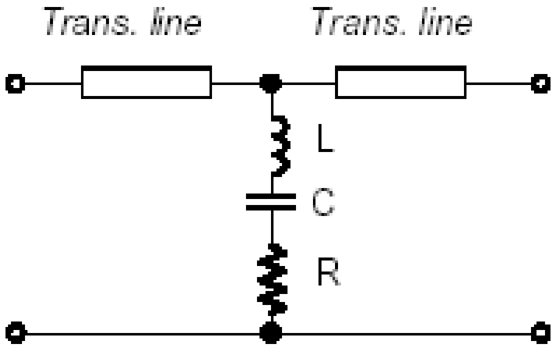

Fig 3: Equivalent circuit of unloaded CPW

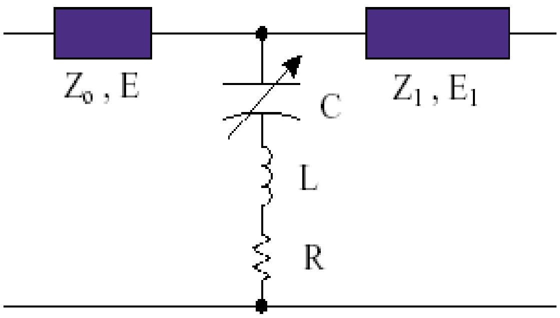

Fig 4: Equivalent circuit of loaded CPW

III. DESIGN OF DMTL CPW PHASE SHIFTERS

The length of the CPW is 7500µm and it has 10 bridges that are periodically loaded with spacing of 750µm. The air bridge gap is 1-3µm, the tuning frequency range is 38 – 42 GHz and the center frequency is 40 GHz. The heights are varied and their corresponding outputs such as return losses, insertion losses and phase velocity are noted. Fig 5 shows the layout design of coplanar waveguide loaded periodically with 11 MEMS bridges. A constant control voltage applied between the center conductor and the ground produces a force that tries to pull down the MEMS bridge, varying the phase velocity and characteristic impedance.

DESIGN PARAMETERS:

- Conductor width(w) = 100µm
- Substrate dielectric constant ε_r=11.7(silicon)
- Bridge thickness = 0.5µm
- Bridge height = 3µm
- Substrate thickness(H) = 500µm
- Ground width(w+2G) = 300µm
- Gap width(G) = 100µm
- Conductor thickness(t) = 1µm

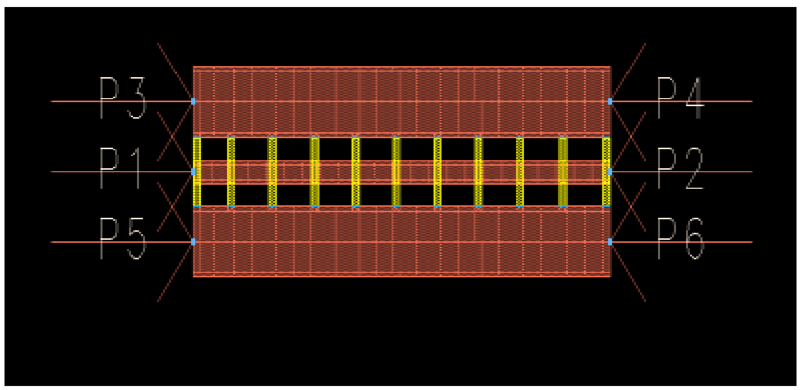

Fig 5: Layout of CPW with 11 MEMS bridges

IV. DESIGN OF BILATERAL INTERDIGITAL CPW PHASE SHIFTER

The simple method of realizing a capacitor in a coplanar wave guide is by providing a slot in the middle of the conductive strip. This will act like a parallel plate capacitor, the capacitance of a parallel plate capacitor is a direct function of the cross sectional area of the conductor, cross sectional area of the strip line of the coplanar wave guide is very small, so it is not possible to realize required value of capacitance using this method. Fig 6 shows the layout of Bilateral Interdigital CPW (BiCPW) structure. Fig 7 shows about the bilateral interdigital coplanar waveguide phase shifter with MEMS bridges.

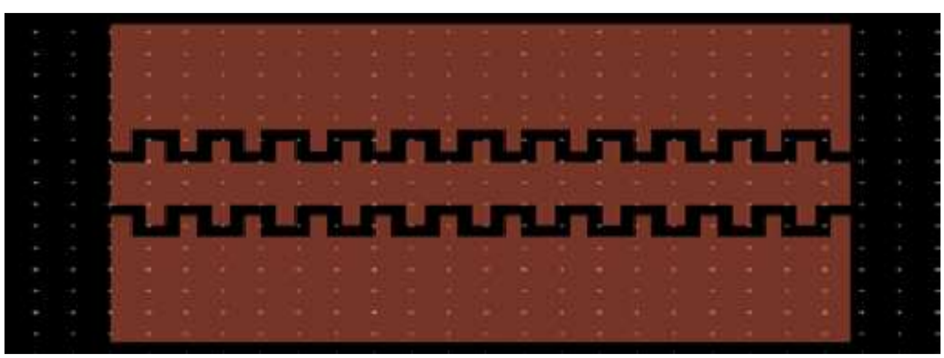

Fig 6: Layout of BiCPW structure

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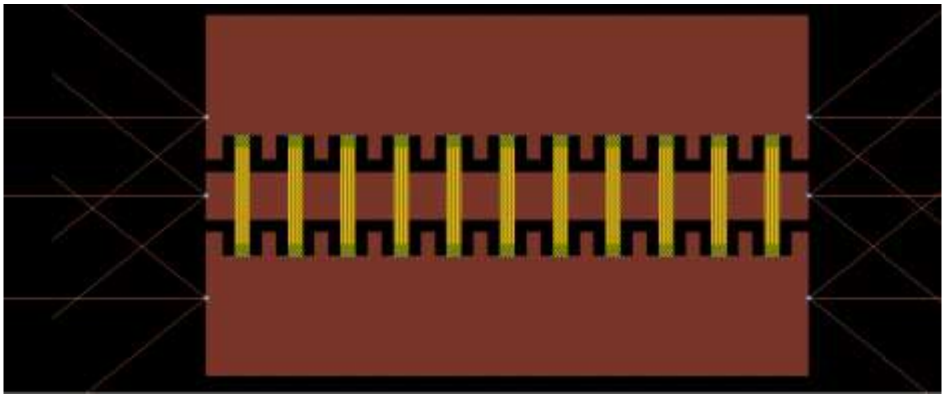
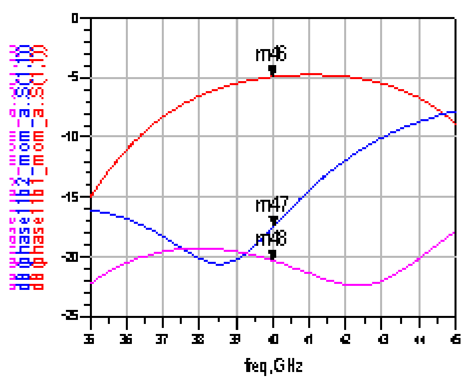


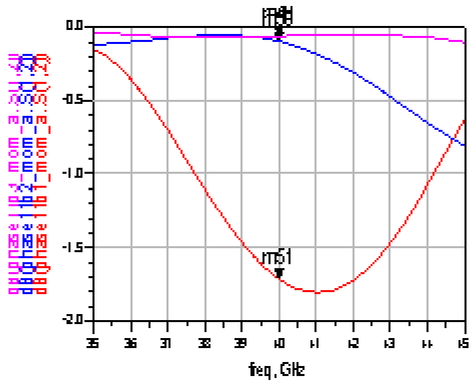
Fig 7: Layout of BICPW phase shifter with MEMS Bridges

V. RESULT & DISCUSSION

The design of MEMS phase shifter on CPW and BiCPW structures are simulated using ADS. The simulation results of phase shifter design on coplanar waveguide is shown in Fig 8a, 8b and 8c which shows the magnitude of S_{11}, S_{12} and phase of S_{12}. Table 1 describes the simulated S-parameters of the conventional coplanar waveguide structure. From the table, the insertion loss in the down state is -0.06 dB and has better return loss of -20dB. The phase shift varies from 144.7 • in up-state to -71.47 • in the down-state.



(a)



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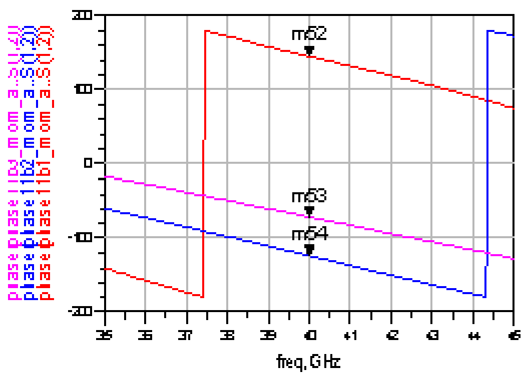


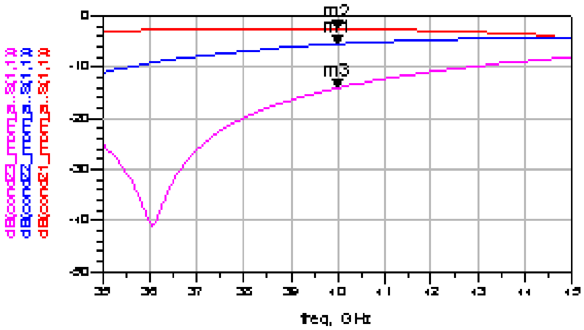
(c)

Fig 8: a. Magnitude of S_{11}(dB) b. Magnitude of S_{12}(dB) c. Phase of S_{12} of CPW MEMS Phase Shifter

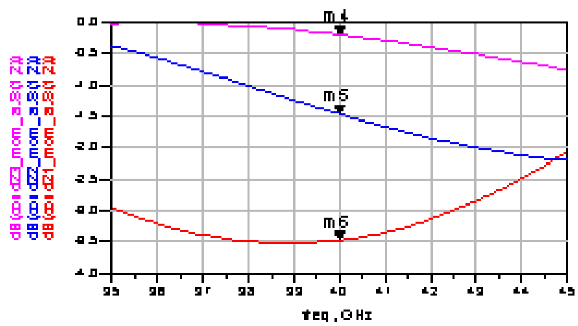
Table 1. Simulation results for magnitude and phase of CPW MEMS phase shifter

Height of bridge								
3µm			2µm			1µm		
S_{11} (dB)	S_{12} (dB)	S_{12} phase	S_{11} (dB)	S_{12} (dB)	S_{12} phase	S_{11} (dB)	S_{12} (dB)	S_{12} phase
-20.274	-0.060	-71.470	-17.442	-0.097	-123.980	-4.925	-1.715	144.71

The simulation results of BICPW is shown in Fig 9. Fig 9a, 9b and 9c shows about the magnitude of S_{11}, S_{12} and phase of S_{12} of BiCPW MEMS phase shifter design. The table 2 shows about the simulation results of various S parameters with various heights.



(a)



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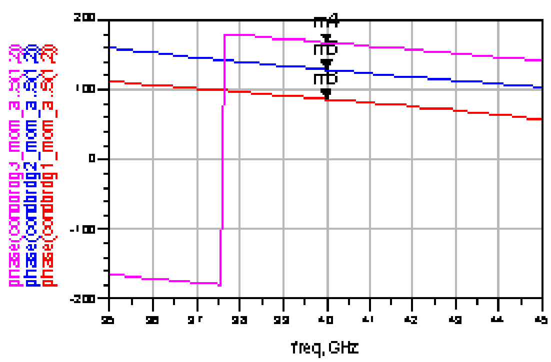

(c)

Fig 9: a. Magnitude of S_{11}(dB) b. Magnitude of S_{12}(dB) c. Phase of BICPW MEMS phase shifter design

Table 2. Simulation results for various heights with bridge

Height of the bridge (µm)	S_{11}(dB)	S_{12} (dB)	S_{12} (phase)
3	-14.05	-0.190	166.08
2	-5.507	-1.458	127.802
1	-2.611	-3.476	85.817

VI. CONCLUSION

A new design of a bilateral interdigital coplanar waveguide (BI-CPW) phase shifter has been designed. The coplanar waveguide with length 3000 µm has an insertion loss of -0.004 dB. The phase shifter using BICPW has a length of 1000 µm and the insertion loss also very low. The phase shift of 3000µm length of CPW is achieved in with minimum length of 1000µm by BICPW. The size is reduced. The length is decreased to achieve the maximum phase shift. The phase shift is 176. This type of phase shifters are suitable to be compactly integrated in the feed networks of high frequency applications like planar phased array antennas. They can provide a very cost effective technology. This can be an effective technology for future wireless RF MEMS devices.

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