Design of Mems Based Tristate Phase Shifter Using COMSOL 4.3b

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Abstract**—**A V-band CMOS-MEMS switchable phase shifter based on reflection-type topology is presented in this work. Phase shifter is simulated by using CMOS process. Three discrete phase states are achieved at 65GHz by using Bi-directional fishbone actuators. The measured insertion is very less and the return loss is also better than 14 dB over the 55-65GHz frequency range. It demonstrates a great potential in many applications.

Index Terms**—***Actuators, CMOS-MEMS, Reflection type, COMSOL MULTIPHYSICS.*

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I. INTRODUCTION

Micro-Electro-Mechanical system.It is the integration of mechanical devices, sensors, actuators and electronics on a common silicon substrate through micro fabrication technology.The three main characteristics of micro fabrication technology are Miniaturization(compact, reliable, very quick response devices),Multiplicity(can fabricate multiple devices easily),Micro Electronics(sensors, actuators).

MEMS are small integrated devices or systems that combine electrical and mechanical components. They range in size from the sub micrometer (or sub micron) level to the millimetre level and there can be any number, from a few to millions, in a particular system. MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices. These systems can sense, control, and activate mechanical processes on the micro scale, and function individually or in arrays to generate effects on the macro scale.

Phase shifter using a distributed MEMS transmission line (DMTL) was demonstrated in [2] with 118° is achieved with a loss of 2dB at 60GHz.The parasitic effects associated with those devices become severe. This effect results in reduction in phase tuning range and increases the insertion loss leading to considerable amplitude distortion. The low breakdown voltages from these devices also limit the power handling capability of the implemented phase shifters. Reflection-type MEMS phase shifters showed an average insertion loss of 4dB and the size of the chip area is 3.15mm^2.MEMS switches are employed for low-loss switching of the line lengths in [3].It can be effectively employed to reduce the loss of reflective phase shifter at milli-meter wave frequencies. Compact size, Low loss makes the phase shifter switches at the range V-band and the above. Millimeter wave application is limited due to the increased loss of the couplers and switches at high frequencies. RF measurements were made using a cascading arrangement covers a wide band frequency from 45MHz to 110 GHz.

A seven-stage phase shifter is constructed by using silicon dielectric blocks -coplanar transmission line. Best insertion loss and return loss for the whole W-band (75 to 110GHz) and in binary-coded phase shifter in [3].

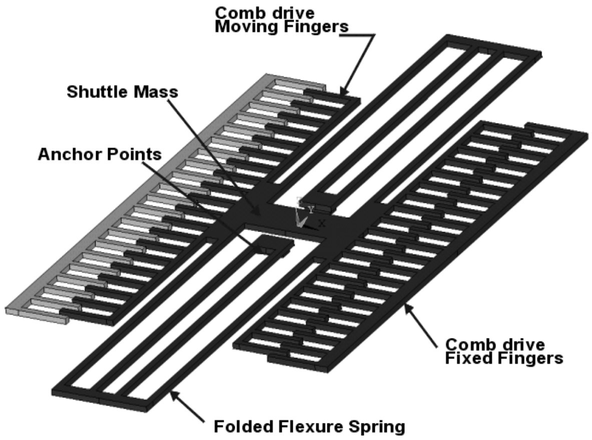

Fig.1. Reflection-type phase shifter

Due to multistage bulk loading phase shifter there will be a maximum loss of 3.5dB. In temperature measurements, the skin effect is adjusted upto 75GHz only. Determination of non-linearity measurements is only possible. Compact wide-band reflective type phase shifter in CMOS technology was demonstrated in [5] with chip area is 0.08mm^2. The developed phase shifter provided 90° continuous phase shift over the V-band range only. CMOS-MEMS phase shifter not only provides a tuning ratio, but also has less parasitic effects, best performance in loss, high cut off frequency & tuning ratio, broadband operation, good power handling capacity and linearity. This work uses lower cost and has high feasibility to integrate with other developed CMOS devices.

II. REFLECTION TYPE PHASE SHIFTER

A typical reflection type phase shifter is composed of a quadrature coupler is terminated by two identical reactive loads. Quadrature coupler is often used to create reflection type phase bits and it is used in most of the reflection type phase shifters. Bandwidth of the coupler is mostly limited by the choice of the coupler. The output signal will become the duplicate of input signal with a relative phase shift.

A. QUADRATURE COUPLER

According to previous work [5], increasing the coupling coefficient can reduce the coupler length. Therefore a defected-ground Broadside coupler is employed to miniaturize the circuit size as well as the insertion loss. The schematic layout of this coupler is shown in fig.1. Initially One coupled line is first routed on the M6 metal layer, and then goes down the combined M4/M5 layer through vias, while the other coupled line is first place on the combined M4/M5 layer and then altered to the M6 layer. This complementary cascade arrangement is chosen in purpose to enhance the output signal balance of the coupler. The portion of M1 beneath the coupled lines is removed to eliminate the line-to-ground capacitance in order to achieve over-coupling condition.

B. ELECTROSTATICALLY DRIVEN COMB ACTUATOR

An actuator is a type of motor for moving or controlling a mechanism or system. It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), or a human or other agent.

The comb-drive actuator is one of the widely used and well-developed prime movers for microelectromechanical systems (MEMS). It is capable of delivering force in the range of µN and up to a few mN with a good design. The stroke length and the force depend on the overall lateral size of the actuator and its thickness.

Capacitive comb drives are commonly used both as actuators and position sensors. For actuators, electrostatic forces typically pull on a MEMS flexure to provide highly accurate position control. The following model focuses on the other common usage of comb drives: position measurement. Many approaches exist for positional measurements with MEMS devices including changes in capacitance or inductance, optical schemes, and others. Of these, capacitance measurement is the most widely used, particularly in microaccelerometers.Static comb drives are relatively easy to set up in COMSOL Multiphysic. They typically consist of a series of interdigitated rectangles of the same size. Thus you can create one rectangle and reproduce it in a regular pattern it to create the fingers of a comb.

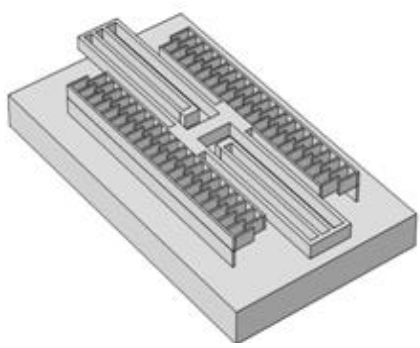

Fig.2. Electrostatically driven comb actuator

When the bias voltage is applied on the electrode, an attractive force is generated to pull the lateral beams towards the biased electrodes, consequently changing the gap between the fingers as well as the capacitor value. Note that the electrodes are comprised of multiple cantilever beams, resulting in fishbone-like structure. Therefore, a smaller actuation voltage is needed foe operation due to the increase of electrostatic force. The entire actuator is constructed by stacked metal layers (M1 to M6) to increase the mechanical reliability.

III. RESULTS AND DISCUSSION

A. ELECTRIC POTENTIAL

Add an Electric Potential node from the Electrode submenus for boundaries, edges and points. This feature sets the potential typically at the interface between the electrode and the current collector or current feeder.

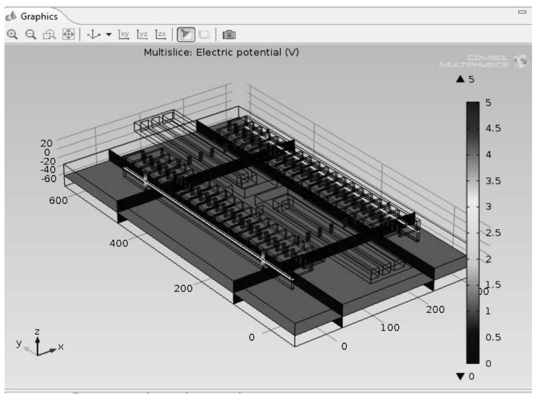

Fig.3. Simulation result of Electric potential (Multislice)

B. DISPLACEMENT

The Prescribed Displacement node adds a condition where the displacements are prescribed in one or more directions to the geometric entity (domain, boundary, edge, or point).The prescribed displacement is applied for moving comb fingers.Displacement is observed high at the tip of the movable beam.

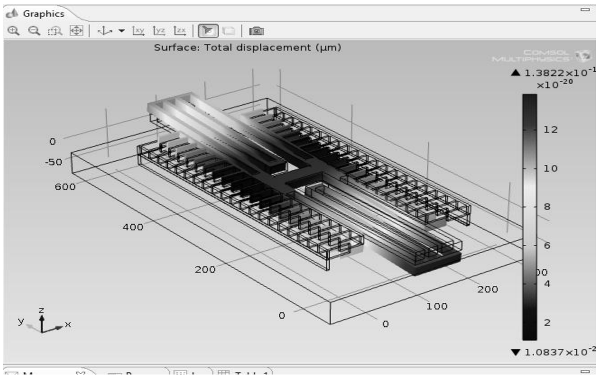

Fig.4. Simulation result of displacement

C. CAPACITANCE

In an electrostatically tunable parallel plate capacitor you can modify the distance between the two plates when the applied voltage changes. For tuning of the distance between the plates the capacitor includes a spring that attaches to one of the plates. The gaps between the fingers are varied such that the capacitor values are changed.

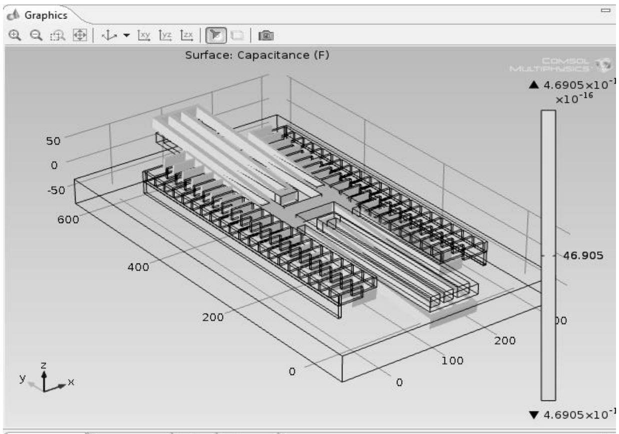

Fig.5. Simulation result of capacitance

D. STRESS

Stress is observed high at the movable beam.For theoretical evaluation, the Von Mises stress can be computed from the stress component.

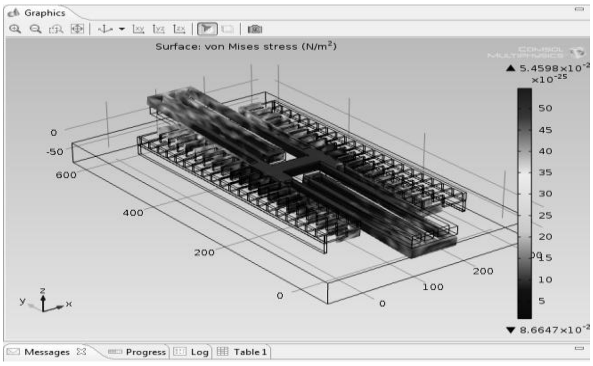

Fig.6. Simulation result of stress

TABLE I

COMPARISION OF DISPLACEMENT WITH VARIOUS GAPS BETWEEN THE FINGERS

GAP BETWEEN FINGERS (µm)	DISPLACEMENT (µm)	CAPACITANCE (µm)	STRESS (µm)
10	5.7245e-19	2.84e-15	2.7252 e-26
20	5.8662e-18	4.517e-15	5.4235 e-22
50	2.224e-19	5.4628e-15	1.4825 e-23

IV. CONCLUSION AND FUTURE SCOPE

An eleectrostatically driven comd drive actuator is designed using COMSOL MULTIPHYSIC.Phase states are obtained by changing the gap between the comb drive fingers.In addition M1 to M6 metal layers are used as couplers and aportion of metal layer beneath the M1 is removed in order to eleminate the line to ground capacitnace to avoid over-coupling condition.

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