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Microswitch Beam-Steering Grid

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Abstract — **We propose new microswitch beam-steering grids to operate at 90 GHz and 240 GHz. The microswitch beam-steering grid has potential advantages over mechanical-scanning devices or active beam-steering reflectors based on diode grids such as lower loss and simple control circuits. Simulations predict that a 4-bit controlled 10-layer microswitch beam-steering grid can have phase-shift resolution of 22.5° with a loss of 1.6 dB and a maximum phase error of 5° at 240 GHz.**

INTRODUCTION

Electrically scanned beam-steering systems allow a beam to shift rapidly, so that several targets can be tracked simultaneously. Previous work considered periodic structures loaded with diodes for millimeter-wave beam-steering systems. Chekroun *et al.* proposed Radant, a three-dimensional grid of diodes for steering a beam [1]. Lam *et al.* demonstrated a phase shift of 70° with a 7 dB loss at 93 GHz on a 2 cm square GaAs diode grid with 1600 Schottky-barrier varactor diodes [2]. Recently, Sjogren *et al.* have demonstrated electronic beam-steering and focusing on a diode grid with 8640 diodes [3]. In these designs, it is extremely important to keep series resistance of diodes as low as possible to reduce losses.

Petersen developed micromechanical SiO_2 membrane switches on silicon [4]. These switches are electrostatically controlled with metal-to-metal contacts (Fig. 1). The series resistance of the switch is very low, only $2\,\Omega$. Switches were demonstrated with switching voltages between 20 V and 62 V and a switching time of 40 μs. We propose a novel beam-steering method which uses these microswitches instead of diodes [5]. Shown in Fig. 2 is one waveguide element in the grid. To change the phase of propagating wave, we utilize the two states of the microswitches. When the switches close, a shunt inductive reactance is presented to the incident wave, and when the switches open, a shunt capacitive reactance is presented to the propagating wave. The metal pattern in the waveguide provides the required reactance.

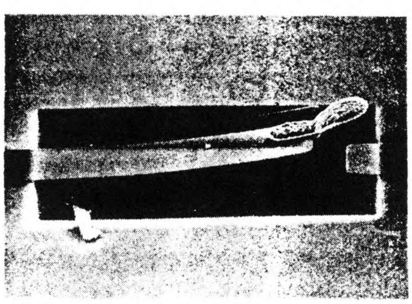

Figure 1: A micromechanical SiO_2 membrane switch on silicon. It is about 100 μm long. *Work of Kurt Petersen at IBM [3]*

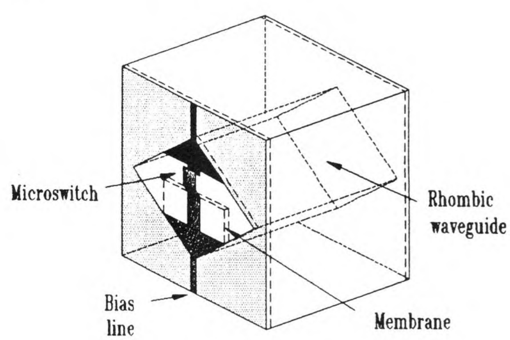

Figure 2: One waveguide element with one microswitch. An electrostatic voltage applied on the bias line operates the switch.

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Approach

We plan to fabricate microswitches on ⟨110⟩ orientation silicon wafers in a periodic pattern. By using an anisotropic etchant (KOH), rhombic waveguides with ⟨111⟩ walls can be formed. Fig. 3 shows the structure. The whole structure will have 10 lapped layers in order to create a 2π phase shift. Each column is controlled by parallel bias lines, which will provide the elements in the same column with the same phase shift. By changing the settings of switches in different layers, different phase shifts can be achieved. Design and simulations were done for ten lapped grid layers with ten microswitches and ten sections of rhombic waveguide. Circuit model and simulation results are shown in Fig. 4. The series resistance is assumed to be $2\,\Omega$ at 240 GHz, the electrical length of each waveguide section is 102°, and the characteristic impedance of the rhombic waveguide is $587\,\Omega$ by calculation. By switching the microswitches to change the reactance in different layers, 4-bit control should be possible to create a 360° phase shift with a resolution of 22.5°. The maximum loss is 1.6 dB, including conductive loss, reflection loss and skin-effect loss for different switch settings. The maximum phase error is 5°.

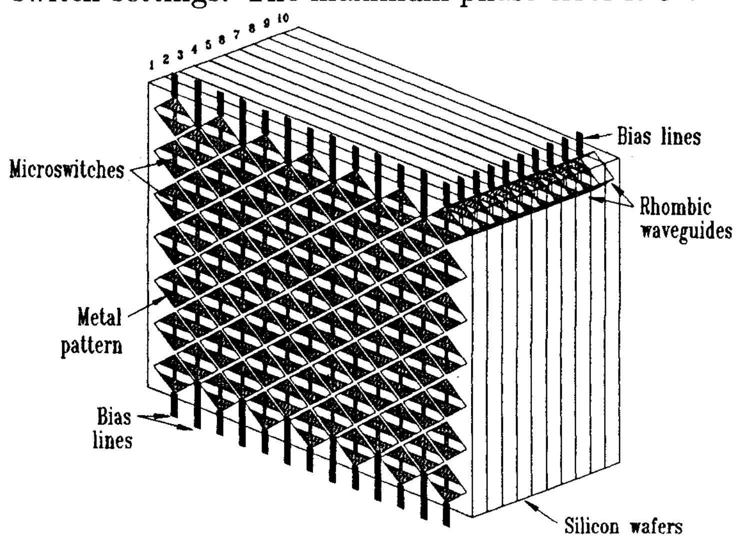

Figure 3: Design of the microswitch beam-steering grid with ten switch layers.

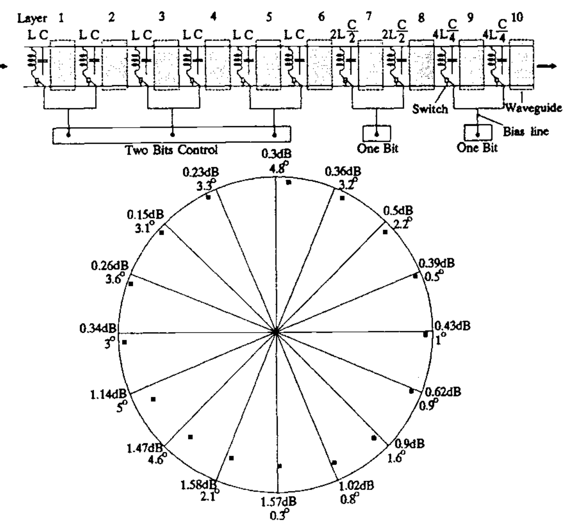

Figure 4: Circuit simulation results: plot of magnitude and phase of transmission coefficients on a polar plot. The shunt elements are L= 514 pH and C=0.86 fF.

Acknowledgments

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