Low-loss Silicon MEMS Phase Shifter at 550 GHz

S. Rahiminejad[1], M. Alonso del Pino[1], C. Jung-Kubiak[1], T. Reck[2] and G. Chattopadhyay[1]

Submillimeter-wave spectrometer and radiometer instruments provide essential information for remotely studying atmospheric composition, measuring the surface properties of cold bodies. Submillimeter-wave radars are currently being developed to measure a variety of new science objectives such as cold ice and comet particle density and velocities. Unfortunately, all of these instruments require mechanical scanning or even re-orientation of the spacecraft to map a scene due to a lack of low-loss phase shifters at these frequencies. A phased array antenna with integrated phase shifters can steer the main beam electronically. Integrated circuit technologies such as SiGe and CMOS are most commonly used to fabricate phase shifters, however, they cannot operate above 300 GHz without considerable loss. This work presents a low loss MEMS phase shifter operating at 550 GHz with up to 180° phase shift, Fig. 1.

The phase shifter consist of a silicon MEMS motor that moves an electrically thin slab into the E-Plane of a hollow waveguide. When the dielectric slab is inserted into a hollow waveguide, the phase velocity of the incoming wave is decreased, thus it results in a phase shift. The slab is designed to have 180 degree phase shift when it is fully inserted into the waveguide, and it can be tuned from 0 to 180 degrees when the slab stands in an intermediate position. The permittivity of the silicon slab is lowered in order to improve the reflection coefficient. This permittivity is synthesized by etching subwavelength hexagonal holes inside the slab [1]. Depending on the silicon-to-air ratio in the slab, the permittivity can be anything between 1 (air) to 11.9 (Si), however, the fabrication constrains the minimum permittivity of 1.6. Simulations shows a 180° phase shift at 550 GHz, with a reflection below -25 dB and a transmission above -0.14 dB throughout the frequency band, 500-600 GHz.

The MEMS motor consists on a large deflection electrostatic actuator previously developed for a compact submillimeter-wave waveguide switch [2]. The comb-drives and beams have been designed to have a deflection of +/-100 um without reaching the onset electrostatic instability. The comb teeth have a uniform length to ensure an almost linear response on the movement of the slab as a function of the voltage. The motor also contains an extra pair of combs that move together with the slab and allow monitoring the position of the slab by measuring the interdigitated capacitance.

The MEMS motor and dielectric slab are fabricated using Deep Reactive Ion Etching on a SOI wafer. The SOI wafer has a device layer of 30 μm corresponding to the thickness of the slab and motor and a handle wafer of 350 μm that provides mechanical support. The waveguide synthesized on an E-Plane split-block that is CNC machined. This architecture allows a seamless integration of the receiver with the phase shifter on the same metal block.

The phase shifter is being fabricated and measurement results are intended to be presented at the conference.

The research described herein was carried out at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, under contract with National Aeronautics and Space Administration.

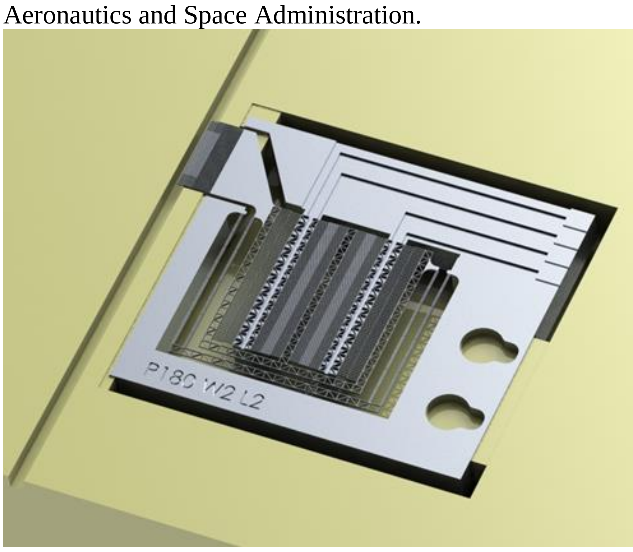

Fig. 1. The Silicon MEMS phase shifter placed in a metal block. The perforated Silicon slab is placed so that it can move freely in and out of the milled waveguide. The MEMS motor is actuated by applying a Voltage over the squared pads.

[1] Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

[2] Was at JPL, now at Virginia Diodes Inc., Charlottesville, VA 22902, USA

References

[1] Menzel C, Rockstuhl C, Paul T, Lederer F, Pertsch T. Retrieving effective parameters for metamaterials at oblique incidence. Physical Review B. 2008 May 29;77(19):195328.

[2] T. Reck, C. Jung-Kubiak and G. Chattopadhyay, "A 460 GHz MEMS-Based Single-Pole Double-Throw Waveguide Switch," *2018 IEEE/MTT-S International Microwave Symposium - IMS*, Philadelphia, PA, 2018, pp. 773-775.

NOTES: