SMWD 2023, KTH Royal Institute of Technology, Stockholm, 23rd – 25th May 2023

Sub-THz Single-Pole-Single-Thru Microelectromechanical Switch

Armin Karimi* (1), Umer Shah (1), Joachim Oberhammer (1)
(1) School of Electrical Engineering and Computer Science, KTH Royale Institute of Technology, Sweden

Summary

This paper presents a novel wideband single-pole-single-thru (SPST) switch fabricated by silicon micromachining and operates based on short-circuiting the dominant mode of the rectangular waveguide. The switch has a compact footprint, with a total size of 2×3.5×1.2 mm. The switching mechanism is implemented by a microelectromechanical (MEMS) actuator with an actuation voltage of ~40 V. It has two operating states of propagating and blocking mode. The measured return loss and insertion loss of the switch are 17 dB and 0.7-1.1 dB at 220-290 GHz in the propagating state. The presented switch also has tuning capability to operate with 20 dB return loss at 220-266 GHz. The measured isolation is also 28.5-32.5 dB in the blocking state at the same frequency span.

1. Introduction

Many studies are dedicated to developing high-performance components operating at mm-wave and THz frequency ranges. Components are preferred to be reconfigurable to reuse the same component in different scenarios. The key element of this reconfigurability is the switches. Switches are among the most critical elements in high-frequency systems. Switches based on rectangular waveguides are utilized in high-frequency systems for signal routing, signal control, frequency band selection in filter banks, and beam steering antenna applications.

More sophisticated switching circuits, such as SPDT and SPQT switches, can be implemented using simpler building blocks of SPST switches, so it is critical to have high-performance SPST switches. MEMS switches fabricated by silicon micromachining have the potential to combine the advantages of both mechanical and semiconductor switches [1]–[3]. They can replace the existing switching technologies since they offer low insertion loss, high isolation, high linearity, large operation bandwidth, low power consumption, switching speed in the microsecond range, and high miniaturization. Compactness and tuning ability are distinguishing features that make MEMS switches suitable for many applications.

2. Design, Fabrication, and Characterization

The presented SPST switch operates based on short-circuiting the dominant mode of rectangular waveguide in its blocking (OFF) state and not affecting the wave propagation in its propagating (ON) state. This SPST switch uses two sets of reconfigurable surfaces (RSs) and can achieve low return loss and high isolation by engineering the cavity resonance between them. The switch is designed in four layers of silicon-on-insulator chips that are gold-sputtered and vertically stacked. The reconfigurable surface consists of vertical and horizontal cantilevers that are in contact in the OFF state and separated from each other in the ON state. A large number of vertical cantilevers increases the OFF state isolation and negatively influences the ON state return loss and insertion loss. On the contrary, A large number of horizontal cantilevers lead to better ON state performance and deteriorate the OFF state isolation [3]. The total number of vertical and horizontal cantilevers is specified by considering this trad-off. The distance between the fixated and moveable cantilevers is 20 µm in the ON state, which allows the wave to propagate through the reconfigurable surface. The movable cantilevers move toward the fixated ones by an integrated MEMS actuator and block the wave propagation in the OFF state. The switch is designed to be robust against the cantilever gap in the OFF state, and its performance is still promising if the gap is as large as 200-250 nm.

The input ports are standard WR-3.4 waveguides, and the chip is aligned to the measurement setup by the internal alignment pins. The waveguides and other features are patterned by deep-reactive-ion-etching (DRIE) process in a cleanroom environment. The measurements are carried out by a Rohde & Schwarz ZVA-24 VNA with ZC330 frequency extenders. The fabricated device can be mounted directly on the standard flanges and sandwiched between them, as the input and output ports are located axially on the front and backside of the chip. Figure 1.(a) shows the configuration of the measurement setup in which the SPST chip is mounted on the standard WR-3.4 flange. Two scanning electron microscope pictures of the switch cantilevers and the waveguide are also shown in Figure 1.(a). According to Figure 1.(b), the measured insertion loss of the switch is 0.7-1.1 dB at 220-290 GHz in the ON state. The measured return loss of the switch is also shown in Figure 1.(b), and it is better than 17 dB in the ON state, ~28 % fractional bandwidth. The isolation of the switch is almost constant over 220-290 GHz, and it is between 28.5-32.5 dB in the OFF state (Figure 1.(c)).

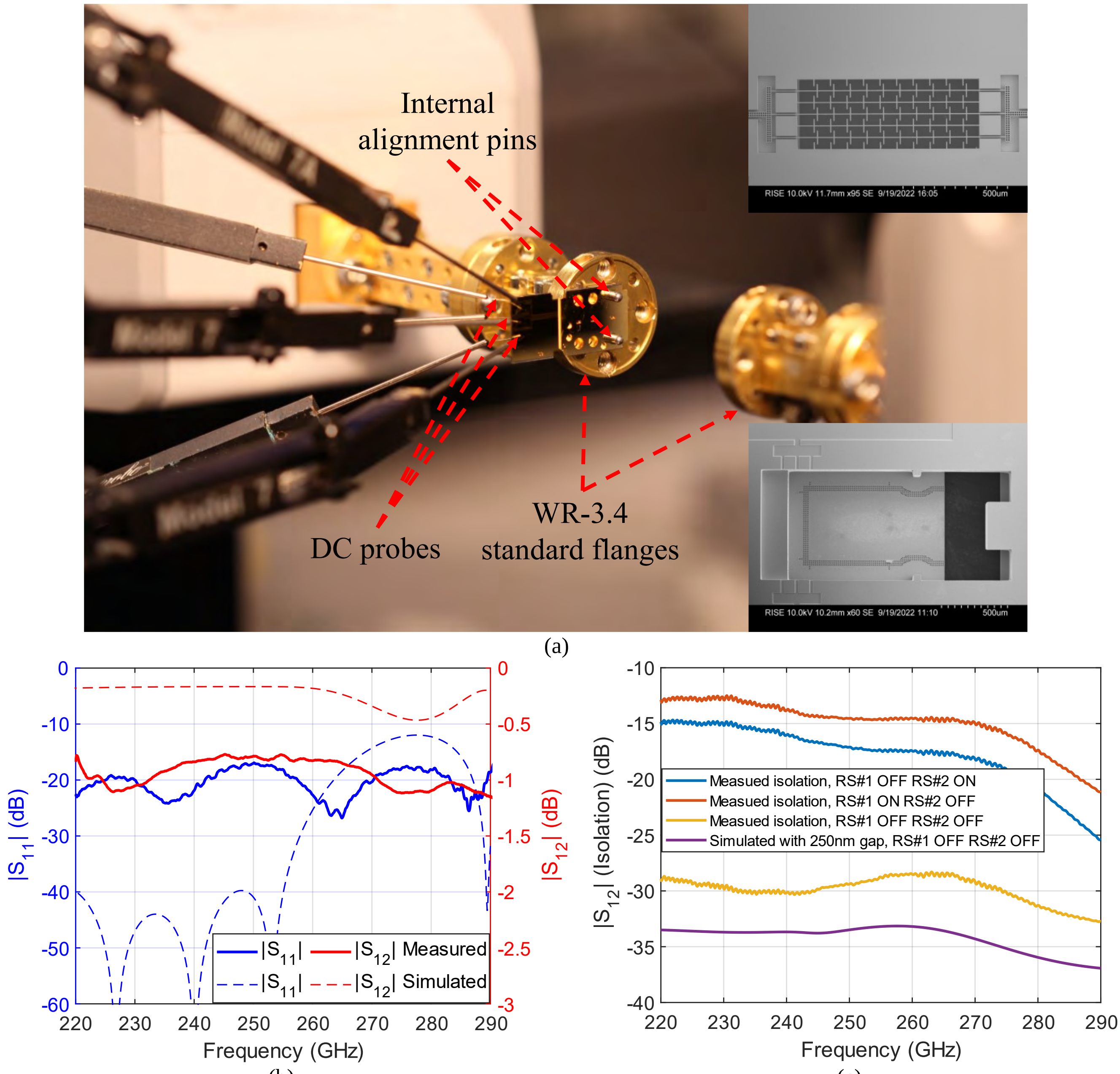

Figure 1. (a) An overview of the assembled chips mounted on the standard WR-3.4 waveguide flanges in the measurement setup and actuated with DC probes. The measured and simulated (a) insertion loss and return loss of the switch in the ON state, and (b) isolation of the switch in the OFF state in different modes. RS stands for reconfigurable surface.

3. Acknowledgements

This research was partly funded through the CAR2TERA project within the European Union's Horizon 2020 research and innovation program under grant agreement No 824962.

References

[1] M. Daneshmand, S. Member, and R. R. Mansour, "Multiport MEMS-Based Waveguide," *IEEE Trans. Microw. Theory Tech.*, vol. 53, no. 11, pp. 3531–3537, 2005.

[2] T. Reck, C. Jung-Kubiak, and G. Chattopadhyay, "A 700-GHz MEMS Waveguide Switch," *IEEE Trans. Terahertz Sci. Technol.*, vol. 6, no. 4, pp. 641–643, 2016.

[3] C. Shah, Umer, Jung-kubiak, G. Chattopadhyay, and I. Mehdi, "A 500 – 750 GHz RF MEMS Waveguide Switch," *IEEE Trans. Terahertz Sci. Technol.*, vol. 7, no. 3, pp. 326–334, 2017.