National Aeronautics and Space Administration

Contactless rotating MEMS switch module for water detection at 557 GHz

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Objectives

The objective was to demonstrate a switch module consisting of a milled block designed to fit any heterodyne spectrometer system (i.e. the receiver, the antenna and the load) and a silicon contactless rotating MEMS switch, both designed to be operated at 500-750 GHz. This module would replace the large flip-mirror currently being used in systems in need of calibration while for example remotely detecting water at 557 GHz. The block would have three connecting sides to be able to connect to the receiver, the antenna and the load , all parts of a heterodyne spectrometer system, at the same time. By actuating the MEMS switch inside, the module would be able alternate the connection from the receiver port to either the antenna port or the reference load port, Fig. 1.

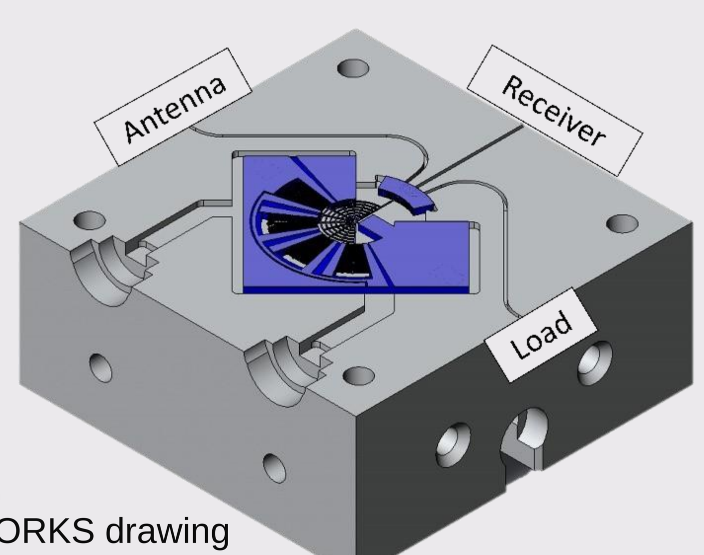
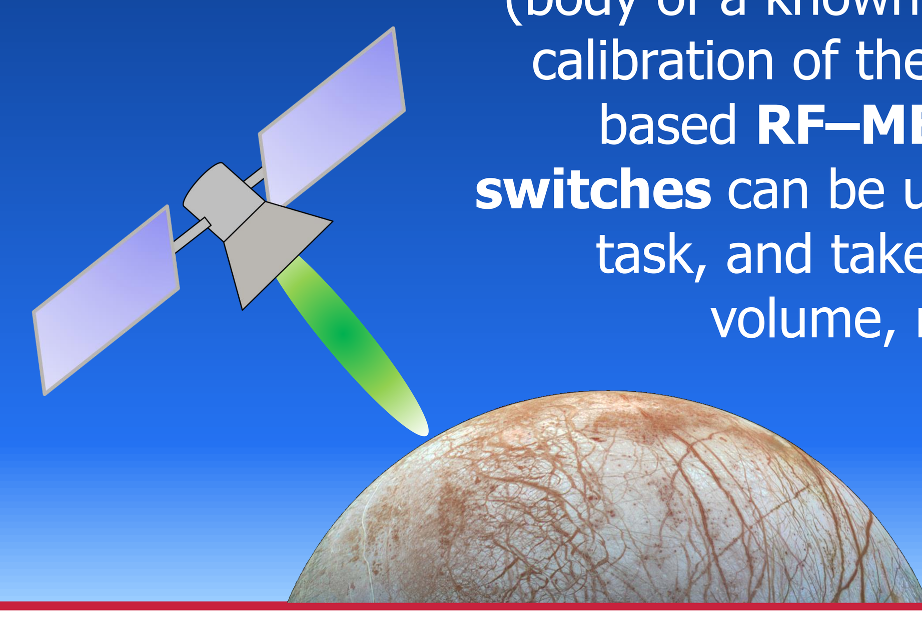


Figure 1. SOLIDWORKS drawing of the block, with the three waveguide ports marked.

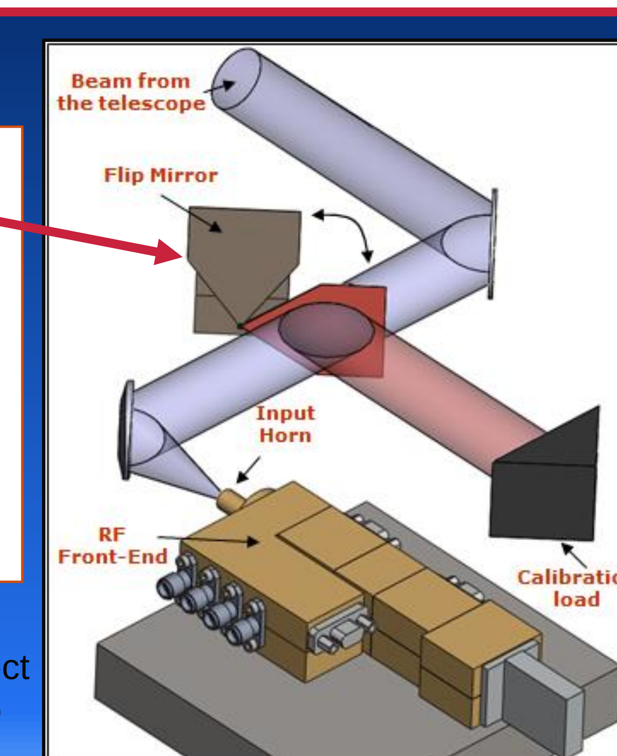
Background

Today high-resolution heterodyne spectrometers suited for space missions are used to detect unique molecular signatures, such as **water molecules**, with a high spectral resolution over a wide range of wavelengths. **The radar and its antennas form a significant part of the system.**



In these systems, a flip-mirror is often used to switch the signal between the antenna and the load (body of a known temperature) for calibration of the receiver. Silicon-based **RF–MEMS waveguide switches** can be used for the same task, and take significantly less volume, mass and energy.

Flip mirror: to optically redirect the radiometer to its calibration target



State of the art beam steering system with calibration mirror

All of the MEMS waveguide switches developed to date need electrical and/or mechanical contact to block the wave, creating issues such as mechanical stress/stiction, and if cycled many times, problems with ohmic contact resistance can arise.

A contactless in-plane MEMS waveguide switch would therefore be greatly beneficial for THz applications.

Approach and Results

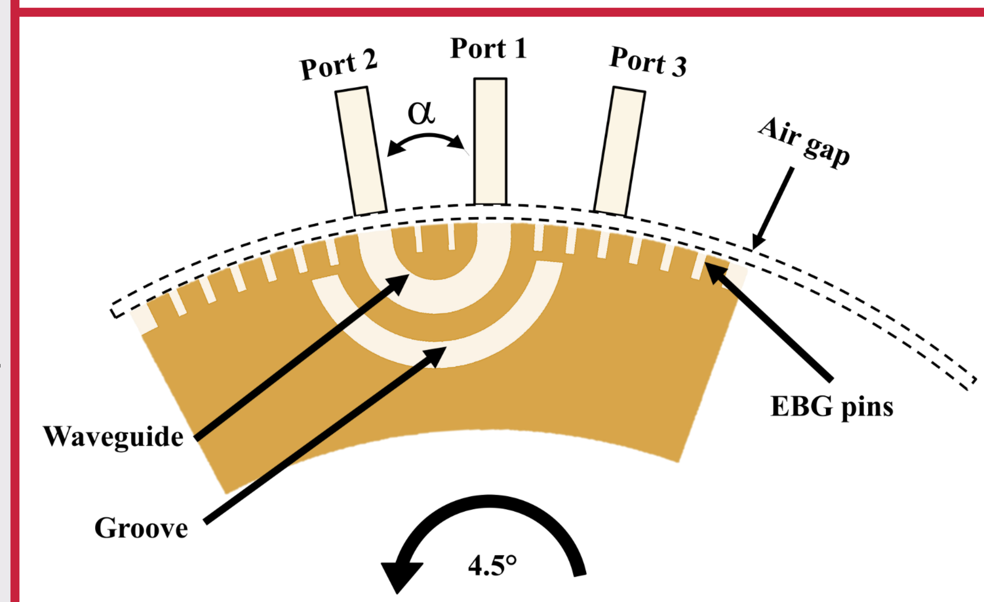


Figure 2. Waveguide section of the switch while actuated. When actuated, the waveguide section will rotate and either connect port 1 to port 2 or port 1 to port 3, depending on which direction it rotates. There is an air gap to avoid contact, and the pins together with the opposing surface creates and electromagnetic bandgap (EBG), thus hindering the wave from propagating to the sides, even though there is no contact between the ports.

- **A new rotating MEMS motor** design was combined together with the waveguide section seen in Fig 2.
- The new silicon contactless rotating MEMS switch was **fabricated in the MDL cleanroom** with a 40-step process, Fig. 3. The fully fabricated device can be see in Fig. 4.

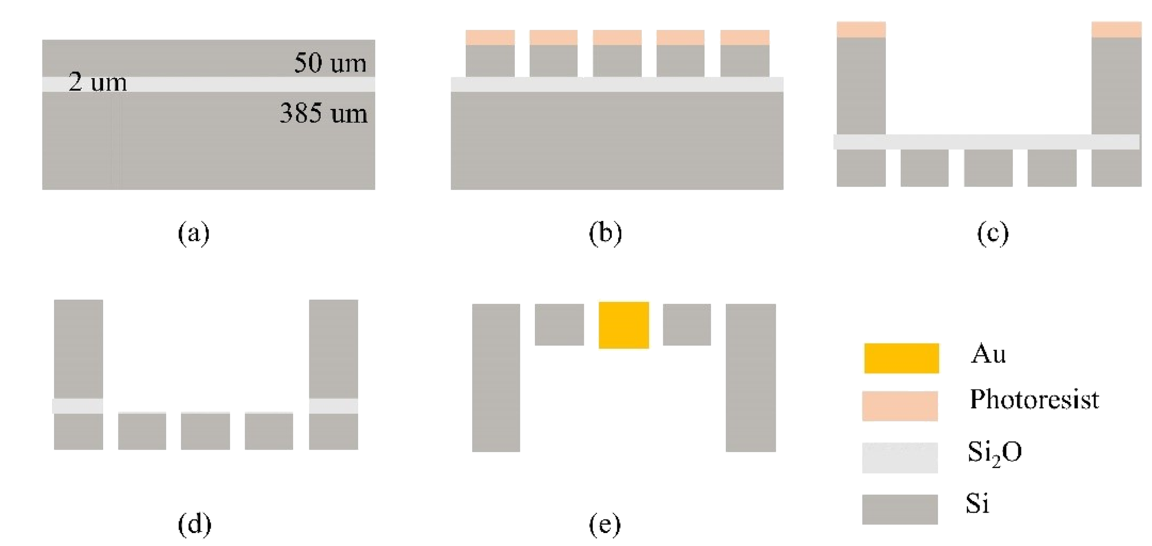


Figure 3. Process flow for the Si MEMS phase shifter. a) SOI wafer (50um/2um/385um) b) Front side of the wafer is patterned and etched with DRIE. c) The wafer is flipped upside down and the back side of the wafer is patterned and etched with DRIE. d) The BOX is removed from the back using dry etching. e) the key parts are covered with Au.

- The electro-mechanical properties were evaluated by applying a voltage and measuring the rotation, **the switch rotates the full 4.5deg at 90V**, Fig. 4.
- **The switching effect** was measured by measuring the transmission and reflection at the different ports for different voltages , Fig.5.
- **The measurements show** how the transmission is increased (Fig. 5b) when rotating the switch, however the transmission levels are very low. This is due to leakage at the block and new blocks need to be made to determine the true performance of the switch..

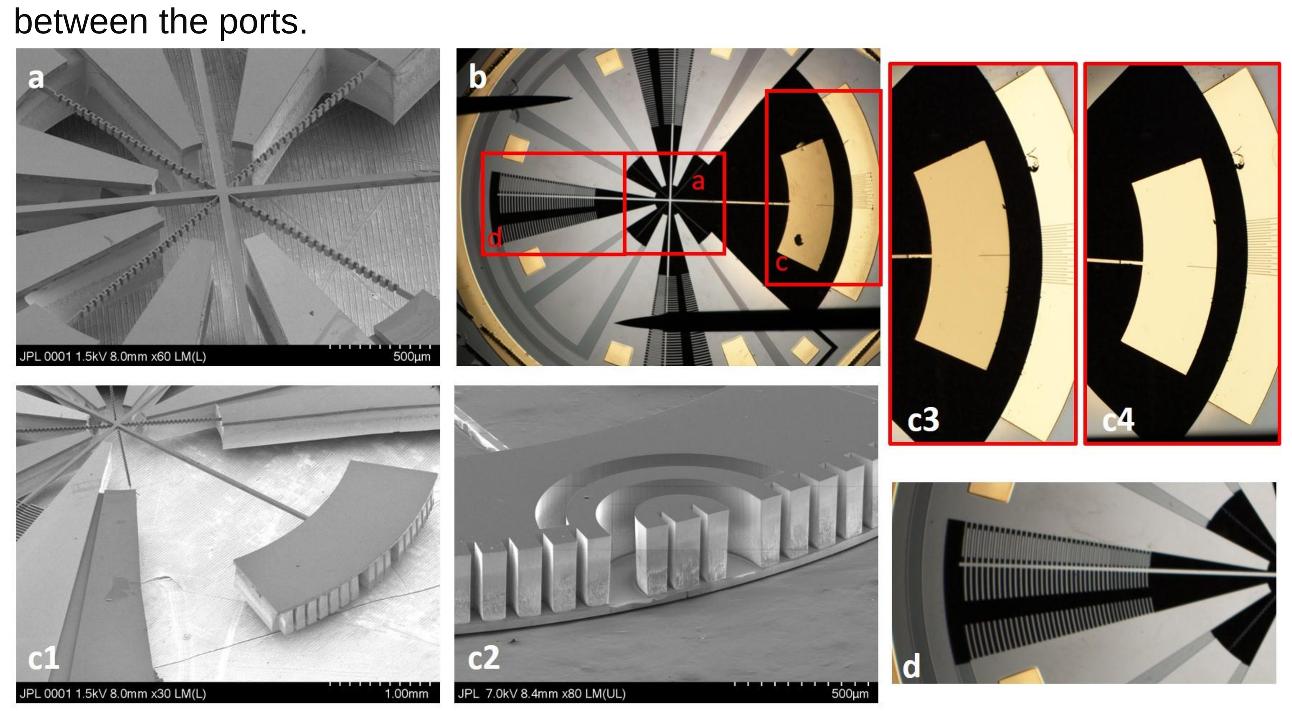


Figure 4. a) SEM of the four springs attached to center of rotation. b) Microscope view of the full device seen from the top, (a) marks where the springs are and (c) marks where the waveguide section is. c1) SEM image of the waveguide section (Fig. 2), seen from the top. c2) SEM image of the waveguide section seen from the bottom. c3) Microscope image of the center line and Vernier lines from the top, when no voltage is applied, 0 deg. c4) Microscope image of the center line and Vernier lines from the top, when voltage is applied, 4.5 deg.

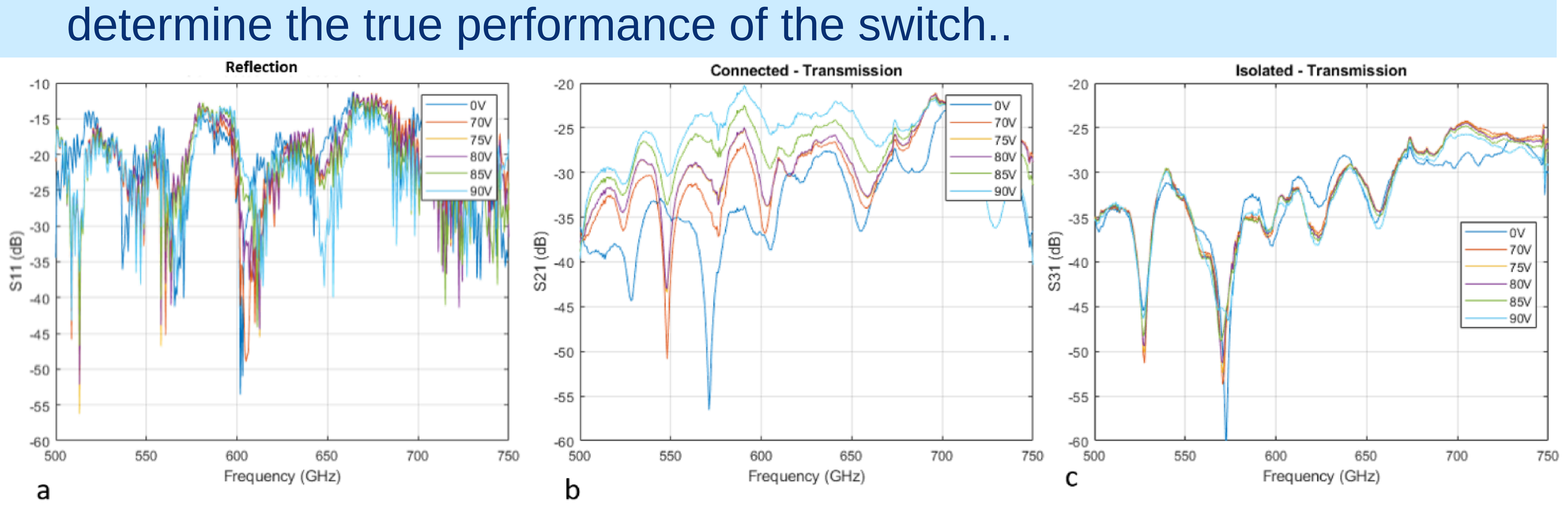


Figure 5. Measurements on the MEMS switch module. a) Reflection (S11) at the receiver port for different voltage (70-90V), when port 1 and 2 are connected. b) Transmission (S21) between port 1 and 2 for different voltage (70-90V), when port 1 and 2 are connected. c) Transmission/isolation (S31) between port 1 and 3 for different voltage (70-90V), when port 1 and 2 are connected.

Significance/Benefits to JPL and NASA

This module is designed to fit any heterodyne spectrometer system at these frequencies and can switch between ports and connect, without having any physical or mechanical contact, thus avoiding common issues associated with today's MEMS switches. The module can replace the large bulky flip-mirrors used in today's remote water detection systems and can therefore reduce the mass and volume of the system. A heterodyne spectrometer system with lower mass and volume can allow other scientific measurement setups to join the same mission.

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