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MEMS, Ka-Band Single-Pole Double-Throw (SPDT) Switch for Switched Line Phase Shifters

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MEMS, Ka-Band Single-Pole Double-Throw (SPDT) Switch for Switched Line Phase Shifters

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Abstract: Ka-band MEMS doubly anchored cantilever beam capacitive shunt devices are used to demonstrate a MEMS SPDT switch fabricated on high resistivity silicon (HRS) utilizing finite ground coplanar waveguide (FGC) transmission lines. The SPDT switch has an insertion loss (IL), return loss (RL), and isolation of 0.3 dB, 40 dB, and 30 dB, respectively at Ka-band.

I. Introduction

Traditionally, solid-state electronic devices such as GaAs MESFETs and PIN diodes have been used to implement SPDT switching networks that are required for switched line phase shifters in phased array antennas. While these devices have performed well and enabled great leaps in radar and communication technologies, they have several problems. They rely on control of current through a semiconductor junction or a metal/semiconductor junction, and there is a resistive loss associated with charge flow that consumes substantial DC and RF power. This consumed power generates heat that must be dissipated, which adds to the system size and complexity. Lastly, linearity is required for modern, wide band communication systems that must process signals with a wide dynamic range, but transistors and diodes are nonlinear devices.

RF/microwave MicroElectroMechanical Systems (MEMS) based devices were first demonstrated by Larson in 1991 [1] as an alternative to solid-state devices for SPDT switches. Since that first paper, several variations of RF MEMS devices have been demonstrated including rotary switches [1], single supported cantilever metal-to-metal contact SPST switches [2], double supported cantilever capacitive SPST switches [3,4], and SPDT switches [5]. All of these MEMS structures have demonstrated substantially improved RF characteristics such as linearity, negligible power consumption, decreased insertion loss and improved isolation.

The SPDT switch described in this paper utilizes MEMS LC devices and $\lambda g/4$ transmission line sections to achieve the desired resonance and response at the design frequency of 26.5 GHz. The SPDT switch utilizing MEMS LC devices described in this paper exhibits greatly improved RF/microwave characteristics, which can make it a desired alternative to conventional GaAs MESFETs and PIN diodes SPDT switching networks.

II. MEMS LC Shunt Device

The MEMS devices utilized in the SPDT switch described in this paper are doubly anchored cantilever beams with three capacitive sections separated by two high inductive segments as seen in Figure 1. MEMS devices incorporating capacitive\inductive sections have been demonstrated [6,7]. This type of MEMS structure allows the switch to be designed for minimum IL and maximum isolation over a wide frequency range. Finite ground coplanar waveguide is used as the transmission line because the narrow width of the FGC transmission lines enable the MEMS cantilever to extend over the entire transmission line with no physical contact between the cantilever and the FGC. This enables the MEMS bias to be applied to the cantilever itself while the FGC line is held at ground or a small potential required to bias other electronic components

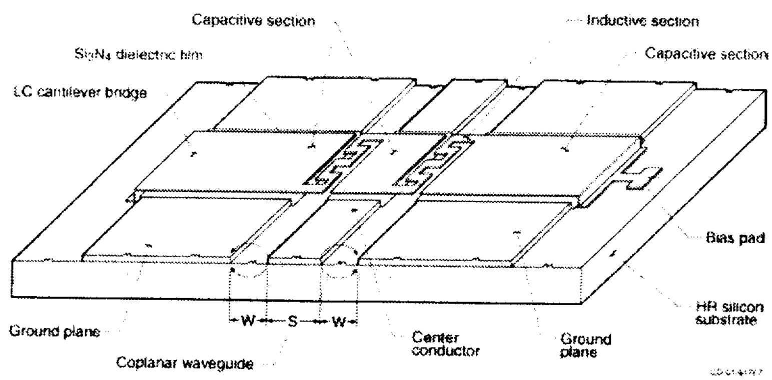

Figure1. MEMS LC shunt device implemented on FGC.

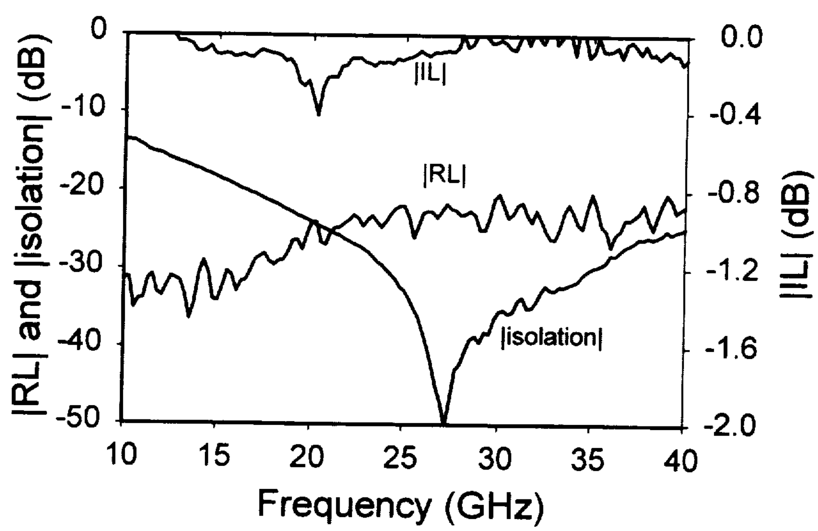

Figure 2: Measured characteristics of MEMS LC device.

The dielectric used to prevent the cantilever from making direct contact with the FGC line is silicon nitride (Si_3N_4), which has a dielectric constant of 8.5

and thickness of 1000Å. The doubly anchored bridge and the FGC lines are fabricated with standard IC processing procedures. The switch is formed by gold plating; the thickness of the gold plated bridge is approximately 1.7μm. The MEMS LC devices as well as the SPDT switch were characterized with the HP 8510C Vector Network Analyzer (VNA) and Multical calibration software developed by the National Institute of Standards and Technology (NIST). The MEMS device requires a 30-volt peak-to-peak 1000Hz AC square wave signal to achieve actuation. The measured characteristics of the MEMS LC device are shown in Figure 2, where it is seen that the IL, RL, and Isolation are 0.11 dB, 23 dB, and 45 dB, at 26.5 GHz, respectively.

III. MEMS Ka-Band Single-Pole Double-Throw (SPDT) switch

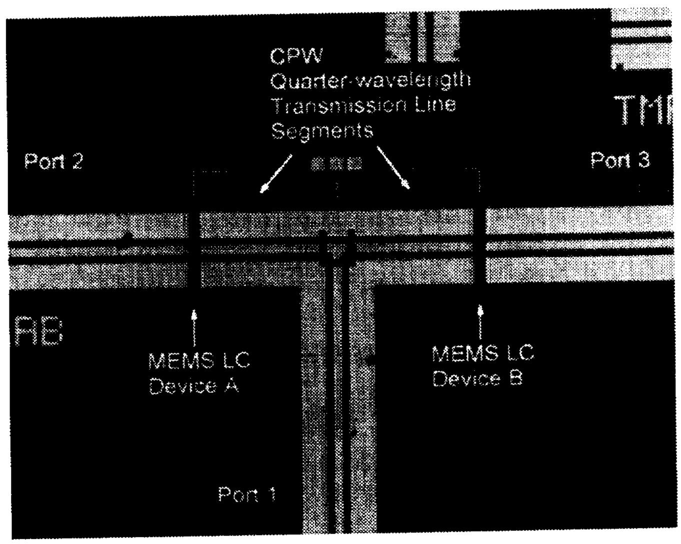

Figure 3. Microphotograph of the SPDT switch.

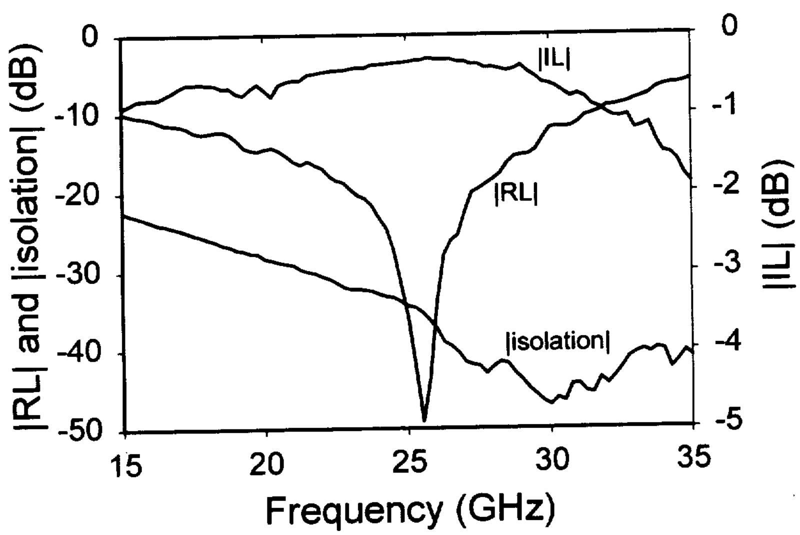

Figure 4: Measured characteristics of MEMS SPDT switch.

The SPDT switch designed in this paper is illustrated in Figure 3. The SPDT switch is a 3-port device with two LC MEMS structures placed a quarter-wavelength from the center of the T-junction as seen in the figure. Distancing the MEMS LC devices a quarter wavelength from the center of the T-junction enables the virtual short realized from MEMS actuation to be transformed to an open at the T-junction thus blocking nearly all the signal from passing to that port. The measured results for the SPDT switch can be seen in Figure 4. The SPDT has a minimum IL, maximum RL, and maximum Isolation of 0.3 dB, 40 dB, and 30 dB, respectively. The MEMS LC devices and the SPDT switch were designed to operate at 26.5 GHz, but due to the Si_3N_4 layer being deposited slightly thicker than designed the isolation is actually greatest at 30 GHz, as seen in Figure 4.

V. Conclusion

A SPDT switch incorporating MEMS LC structures has been reported. The performance of the SPDT switch is excellent and illustrates enhanced RF/microwave characteristic and performance, which makes it a desired alternative to conventional GaAs MESFETs and PIN diodes SPDT switching networks employed in switched line phase shifters for phased array antennas.

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