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Interdigital Bandpass Filter Using capacitive RF MEMS Switches

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ABSTRACT: A band pass tunable RF filter is proposed by using Radio Frequency (RF) Microelectro Mechanical Systems (MEMS). The tunability is obtained by using capacitive MEMS switches that can be tuned within the bandwidth of 3.6 GHz to 4.4 GHz. The performance of the filter depends on geometry and location and types of the MEMS switches. Optimization has been done to achieve tunability by using 3-D high frequency electromagnetic simulator (HFSS).

KEYWORDS: Microelectro Mechanical Systems (MEMS), Radio Frequency (RF), Bandpass Filter, Tunable Filter

1. INTRODUCTION

Wireless and satellite communication, radar, electronic warfare, and instrumentation, all demand tunable filters for flexible and adaptive operations over wide frequency range. Mechanically and magnetically tunable band pass filters, although widely employed and handle high power, provide just low to marginal tuning speed, and are bulky due to their macroscale tuning mechanism. Electronically tuned filters, with compactness and quick tuning, are good candidates for highly integrated systems. However, due to losses and nonlinearity associated with p-n junctions and MOS structures and the complexity in biasing, microwave control devices based on these mechanisms may lack of appeal to current wireless communication applications, and thus investigations into tunable filters based on diodes and transistors have barely reported. Recently, RF MEMS tunable filters of various tuning topologies with much lower insertion loss (IL), nonlinearity and higher Q factor than semiconductor based devices, have been demonstrated as an enabling technology for low cost and high performance integrated military or commercial RF systems. These surface micromachined devices have the advantages of simple (electrostatic) tuning with ultra-low tuning power consumption, large bandwidth and capability of monolithic integration with active circuit.

Existing designs suffer from passband attenuation mostly due to the architecture itself rather than conductor or dielectric loss. Reconfigurable band pass filters (BPFs) draw much attention in modern systems because of their diversity. Reconfigurable BPFs with tunable bandwidth tunable center frequency and switch ability are reported. Among these researches, PIN diodes, piezoelectric transducers, and MEMS cantilever/bridge structures are used as the switch components. In this paper, RF MEMS switches have been proposed to design a reconfigurable interdigital band pass filter and describe the optimization procedure to obtain tunable bandwidth.

II. DESIGN AND ANALYSIS

The filter configuration consists of an array of n Transverse Electro Magnetic (TEM) -mode transmission line resonators, each of which has an electrical length of 90° at the midband frequency and is short-circuited at one end and open-circuited at the other with alternative orientation. Interdigital bandpass filters are commonly used for microstrip implementation. The coupling is achieved by way of the fields fringing between adjacent resonators separated by spacing. Each line element serves as a resonator, except for the input and output line elements, which have an impedance-matching function. The input and output are also using tapped line which offer space and cost-saving

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advantages because the first and the last resonators are eliminated. These types of bandpass filters require use of grounding microstrip resonators which can be achieved via holes.

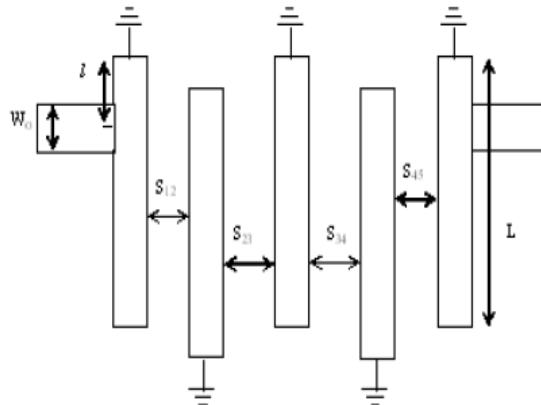


Fig. 1: General Structure For Interdigital Bandpass Filter.

The five resonators are assembled on the alumina substrate in the design. The alumina substrate is placed on the ground plane made of copper plate with 0.5 mm thickness. The filter requires use of grounding of the resonators. The grounding is placed at the side of one end of the resonator and connected to the ground plane via hole through the substrate. The microstrip line is used as the feeding technique.

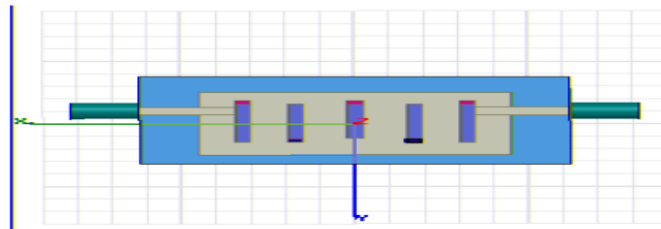


Fig. 2: The Layout Of Inter Digital Band Pass Filter.

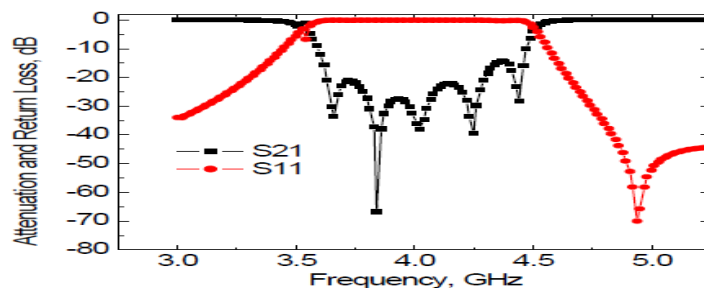


Fig. 3: Simulated Results Of Interdigital Filter Without MEMS Switches.

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2.1 One MEMS Bridge Parallel with the Resonator

The MEMS bridge consists of thin strip of metal (membrane) and insulator that is fixed at both ends. It is suspended above an electrode with spacing, forming a capacitor between these two conductors. The bridge is considered silicon nitride of dielectric constant $\epsilon_r = 6.8$ with copper coating. The dimension of the bridge is $1.689 \text{ mm} \times 14 \text{ mm} \times 0.1 \text{ mm}$. The structure is shown in Fig. 4. The insertion loss and return loss are shown in Fig. 5. The result shows that the bandwidth is decreasing as the distance between the bridge and the resonator becomes closer. The upper frequency is nearly maintained while the lower frequency is changing. Since air is separating the electrode and the switch, the up-state capacitance is small. By applying a voltage the upper membrane is deflected by the electrostatic force, and the membrane will snap down to the opposite electrode. The spacing is also reduced and the capacitance is increased. Electrostatic force between the top and bottom electrodes actuates the switch. The variation in capacitance will disturb the frequency response of the filter. Furthermore, the fringing fields capacitances of MEMS switches depend on the bridge dimensions and height. As a result the lower cutoff frequency decreases to lower value. The results are summarized in Table 1.

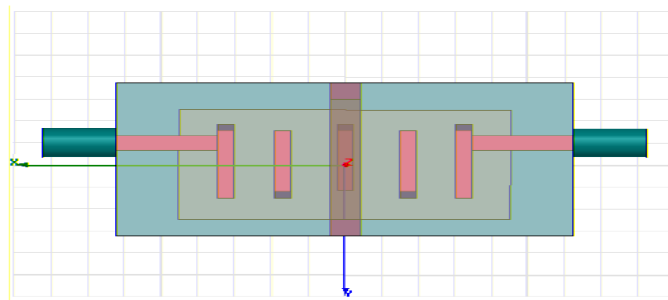


Fig. 4: The Layout Of The Filter With RF MEMS Bridge Placed Above The Middle Resonator.

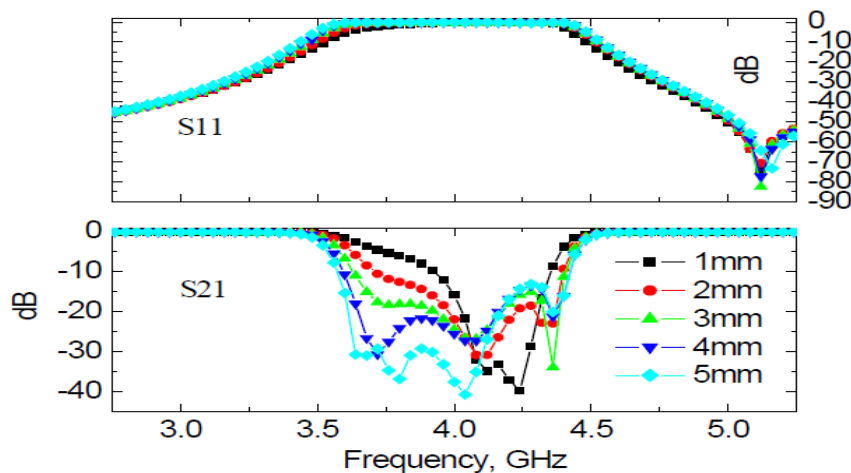


Fig. 5: Simulated Results Of Interdigital Filter With Single MEMS Switch Placed Parallel To The Center Resonator.

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Distance, d (mm)	f_L (GHz)	f_U (GHz)	f_C (GHz)	Bandwidth (GHz)
1	3.640	4.444	4.042	0.804
2	3.570	4.447	4.0085	0.877
3	3.544	4.455	3.9995	0.911

Table 1: The Result For The Filter With Five MEMS Bridges Parallel With The Resonator.

2.2 Two MEMS Bridge Parallel with the Resonator

The performance of the filter is analyzed by turning the switch on and off by placing two bridges parallel to the resonator places beside the centre resonator. It is observed from Fig. 6 that there is not much in difference in bandwidth variation between the filter with placing only single MEMS bridge in parallel with the resonator. However, for two bridges, the bandwidth for the down-state is much wider than the single bridge.

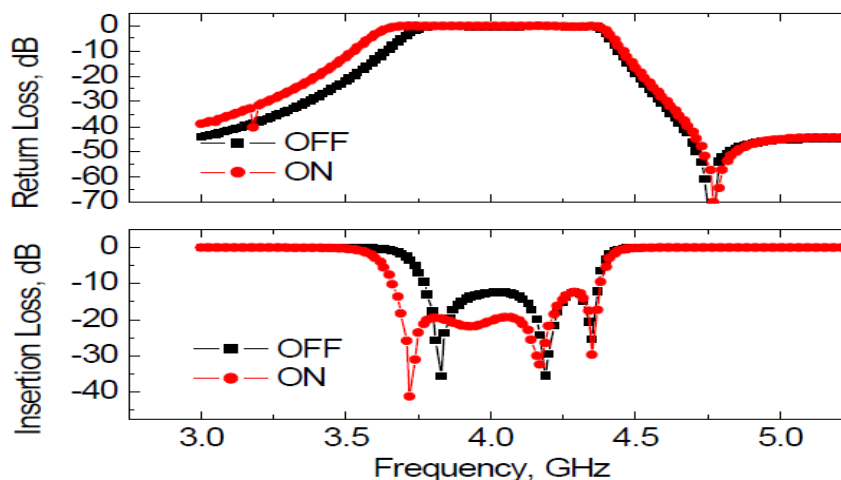


Fig. 6: Simulated Results Of Interdigital Filter With Two MEMS Switches Placed Parallel Beside The Center Resonator.

III. CONCLUSIONS

The RF filters with a higher performance, smaller size, lighter weight, lower cost, low loss, and high selectivity can be achieved by using RF MEMS technology. The designing of the interdigital band pass filter has been presented with the analysis of the frequency responses of the filter. The use of capacitive RF MEMS switch in the application of interdigital band pass filter is investigated in this paper. The designs indicate that the application of capacitive RF MEMS switches in the tunable filter enables the filter to tune the bandwidth in the frequency range of 3.6 GHz to 4.4 GHz, which was the range for the filter design without MEMS switch. The tunability has made the filter suitable to be used in different types of application.

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