Tunable Bandstop Filter using High Power, Speed Handling CMOS RF MEMS Capacitor

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***Abstract* –– Modern signal filters operating at higher frequencies (over 3,000 MHz) which fall under RF and microwave frequencies play a vital role in achieving highly potential and accurate wireless communication systems. This paper provides a peer review on the present available technologies and methodologies in Tunable Bandstop RF Filters. Point outs the exemptions caused as well as the voids they have filled to overcome the disadvantages of the previous technologies. Finally, this paper presents a new age Bandstop RF filter considering all the design parameters.**

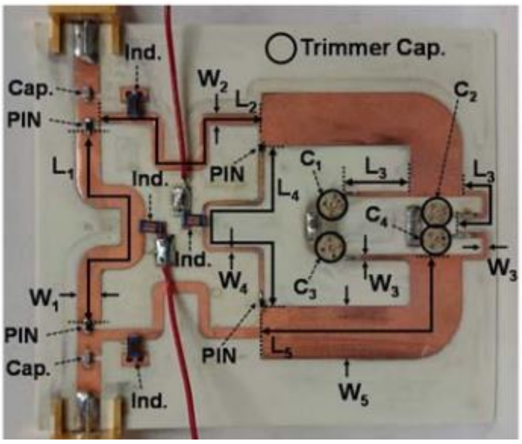
I.INTRODUCTION

The extreme usage of wireless communication networks, systems witnessed over the past few years with the requirement of working with high speed (5G communications) where high requirement of microwave circuits resulted in design of complex and combat RF front ends of their mobile terminals. Where the conventional usage of simple passive elements like capacitors and inductors was failed due to large characteristic impedances of the elements and sources which eventually effected the efficiency of the complete system. This lead to the invention of new class RF capacitors and RF inductors with an ability to work at higher order frequencies. Thereafter with growing usage of these elements resulted in designing RF Transmitters, Receivers, Transceivers, filters with multi-standard and multi-functional operations.

Tunable high selectivity Bandstop filter (BSF) design is one of the strategic radio-frequency (RF) components in the front end of civilian and military communication systems. So the project has to contribute to one of the leading engineering domains. The paper hereafter contains 3 sections. Section II provides the review over the several available technologies in Bandstop filters. Section III provides a review on the available RF capacitors. And Section IV presents a new age Tunable bandstop (TBSF) filter using high power, speed handling CMOS RF MEMS Capacitor

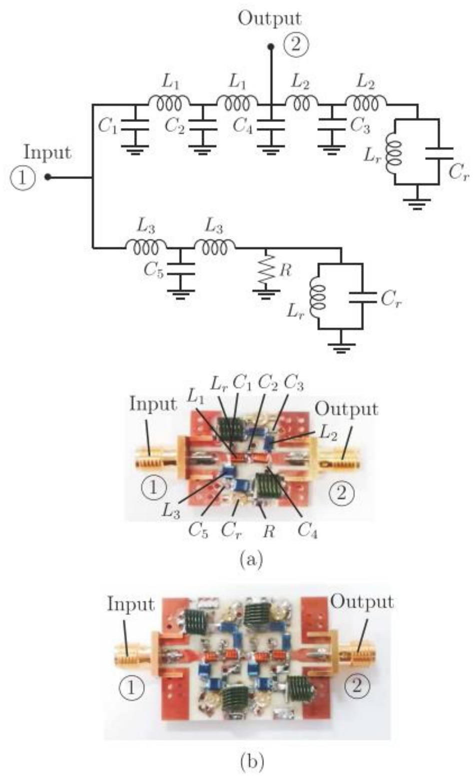
II. RF BANDSTOP FILTER REVIEW

Banstop filters are extensively used to remove an unwanted band of frequencies in a given band. Our present topic, Radio Frequency (RF) filters are used for the frequencies which fall in RF region. Their applications include noise removal in image, signal processing and various acoustic applications. In a generalized way, design of any RF filter required to consider a set of design parameters and are follows. Insertion Loss, Return Loss, frequency range handled, input impedance, cost, design complexity. Insertion loss is a measure of how well a filter attenuates a signal as it passes through the filter. It is caused generally by VSWR of the connector. power dissipated in the dielectric materials (Teflon, rexolite, delrin, etc.). power dissipated due to the conducting surfaces of the connector. It is a function of the material and plating used. The latest Filter prototype proposed in [4]



Photograph of the manufactured multiband BP-to-BS filter prototype. N=2: L1=25, L2=30.9, L3=9.8, L4=31.8, L5=28.8, W1=3.35, W2=1.6, W3=0.81, W4=0.54, and W5=7.77 (all dimensions are in mm).

achieved the appreciable low insertion loss with Theoretically-synthesized power transmission (|S21|) and reflection (|S11|) responses of the multiband BP-to-BS filter concept operating in the BSF mode. Even with an advantage of shifting between Bandpass (BP) to Bandstop (BS) mode, the design became complex because of it. Now, considering the input impedence which causes insetion loss and major damage by the presence of reactive loads since this creates multiple power reflections at their terminals., a filter design which addressed this disadvantage of a bandstop filter has been proposed in [10].Where a class of frequency-reconfigurable input-reflectionless/absorptive RF/microwave filters is presented.

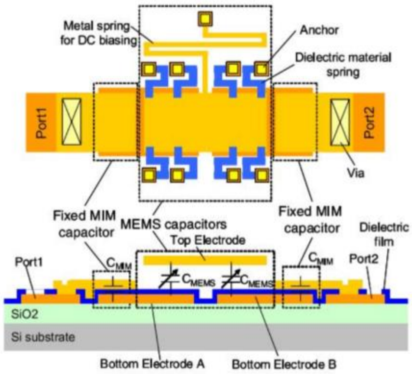


Manufactured single- and two-stage absorptive tunable lumped-element bandstop filter prototypes (L1 ≡ 0908SQ27N, L2 ≡ 1206CS82N, L3 ≡ 100HQ82N, Lr ≡ 1515SQ90, C1 = 5.8 pF, C2 = 8.6 pF, C3 = 2.2 pF, C4 = 5.4 pF, C5 = 3 pF, Cr = 1–5 pF, and R = 740). (a) Single-stage prototype: circuit schematic and photograph. (b) Two-stage prototype: photograph

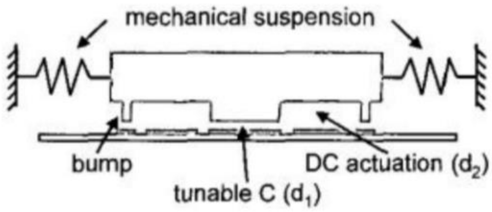
They consist of tunable complementary-duplexer architectures that are composed of a main and an auxiliary channel with opposite filtering transfer functions. Now considering the frequency range handled, all the designs of filters proposed earlier were limited for a frequency of GHZ. This has been achieved by the concept presented in [11], where frequency handling was achieved from GHZ to a few THZ by design, simulation, and analysis of a G-band (140-220 GHz) reconfigurable bandstop filter (BSF) using the waveguide-based configuration. The reconfigurability is enabled by novel optically controlled RF switches with superior performance in the millimeter-to-terahertz (mmW-THz) region.

III. CAPACTIORS REVIEW

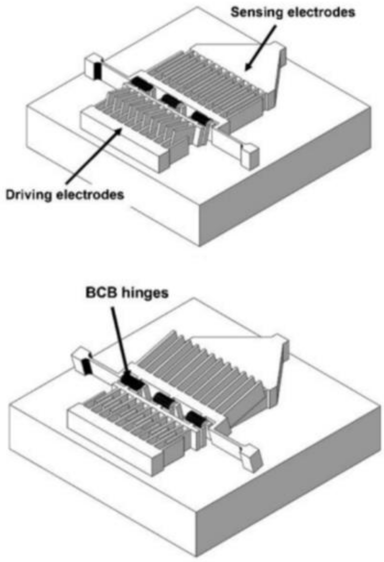
Tunable Filters need Capacitors with variable capacitance, also known as varactors. Tuning of a capacitance is generally achieved by 3 ways, varying the gap between the plates, varying dielectric properties, varying the area of the plates. Designers choose their respective varactor according to the need of their filter circuit. So, for our proposed filter few capacitor designs based on the following parameters, Tuning Ratio, Quality Factor, Frequency range handled have been reviewed. A Quadruple series capacitor has been presented in [3].



The Quadruple series capacitor enables reduction of actuation voltage without disturbing the power handling capability, Since the MIM (metal Insulator metal) capacitor reduces the RF voltage amplitude applied to the MEMS capacitors. Where it can handle a frequency range of 1Ghz, has achieved a quality factor of 80-114, and power handling capacity up to 35dBm, but has a disadvantage due to less tuning ratio. To overcome this, an advancement a Dual Gap relay type design has been proposed in [2]



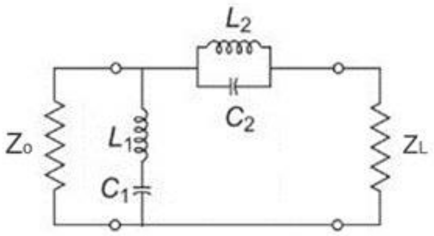
where a Tuning ratio up to 17 has been achieved, quality factor of 150-500, and could handle a frequency range of 1Ghz – 6Ghz. The air gap reduces to less than 2/3 of the original air gap and the suspended top electrode collapses on the bottom electrode. This pull-in can be avoided in a dual-gap relay-type tunable capacitor and a special bumps are arranged at the edges of the structure. Further an Angular vertical Comb-Driven Tunable Capacitor has been proposed in []



where it achieved a tuning ratio of 31, quality factor of 273, frequency range up to 1Ghz has been achieved. Hence, considering all the above proposed capacitors, the Angular Vertical Comb-Driven Tunable Capacitor is being considered for the usage of our proposed Bandstop filter prototype.Since it has an advantage over other types of capacitors of capacitance tunability through area tuning, which has practically null limitations of adjustment of area for the preferred capacitance.

III. PROPOSED BANDSTOP FILTER PROTOTYPE

Considering all the above filter parameters and varactor parameters, a final prototype of Tunable Bandstop Filter has been presented.



The Circuit has been designed Insertion Loss method. Firstly by designing a prototype low-pass filter with the desired pass band characteristics. Transformed this prototype network to the required bandstop type. The proposed filter prototype is basically a first order filter with Butterworth or maximally flat response filter. The load resistance has been considered unity for better analysis of other circuit elements. The required capacitance and inductance values can be obtained from the following table and the given formula.[12]

k	n=1	2	3	4	5	6	7
1	2.0	1.414	1.0	0.7654	0.618	0.5176	0.445
2	1.0	1.414	2.0	1.8480	1.618	1.4140	1.247
3		1.000	1.0	1.8480	2.000	1.9320	1.802
4			1.0	0.7654	1.618	1.9320	2.000
5				1.0000	0.618	1.4140	1.802
6					1.000	0.5176	1.247
7						1.0000	0.445

$$L_k = \frac{g_k Z_L(\omega_2 - \omega_1)}{\omega_0^2}$$

$$C_k = \frac{1}{g_k R_L(\omega_2 - \omega_1)}$$

The proposed Circuit is designed to achieve an Insertion loss of 1.1 dB with and actuation of 5dB. This microstrip realization of the following filter can handled a frequency up to 110-150 GHZ. It has theoretically zero Return Loss. The varactor used in the given circuit is an Angular Vertical Comb Driven Capacitor and the techniques for achieving low insertion loss and zero return loss theoretically has been used from the filter designs presented in [4][10].

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