A Realization Compact Pseudo Chebyshev Low Pass Filters for UHF Band Using RF MEMS Technology

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Abstract— This paper describes the development compact Chebyshev microstrip filter is fabricated by using RF MEMS technology, which laser micromachining techniques are selected. The 5th order Chebyshev low pass filter operating within UHF range have been designed, simulated, fabricated, tested, investigated and implemented on silicon substrate with a band pass ripple of 0.01 dB. The design of lumped element and microstrip circuit filters are simulated and implemented by using Advanced Design System. The simulation and measurement results of microstrip low pass filter have been compared and excellent agreement is observed. Laser micromachining can lead to finer finishes, improved accuracy and less process overhead. The purpose for this work has been focus on laser micromachining into develop compact microstrip circuit. To satisfy these challenging in terms of geometry, machining accuracy, surface finish or processing speed, laser micromachining with diffraction limited beam quality offer many benefits such as small spot size, high power density, enhanced processing speeds, reduced heat affected zone for a range of micromachining applications. Laser micromachining has become a great prospective as a MEMS (micro-electro-mechanical systems) fabrication technique in ever-continuing trend of miniaturization in microelectronics, micro-optics and micromechanics for wireless communication system.

1. INTRODUCTION

The low-pass filters are often employed in many communication systems to eliminate harmonics and spurious signals with demand of compact size, low pass band insertion loss, and high attenuation. Filters can be realized in lumped type or microstrip line type. The lumped-element filter design generally works well at low frequencies, but two problems arise at microwave frequencies. First, lumped elements such as inductors and capacitors are generally available only for limited range of values and are difficult to implement at microwave frequencies, but must be approximated with distributed components. Furthermore, the normal lumped inductors and capacitor components introduce stray capacitance and inductance from leads. The conventional filter design method such as open-stub low-pass filters and stepped impedance low-pass filters are unable to meet the requirements for modern communication systems because of some drawbacks [1]. For low frequency applications large inductors and capacitors are needed causing a bulky system, which is often discouraged. The important of microstrip line has advantages of low cost, compact size, light weight, planar structure and easy integration with other components on a single board.

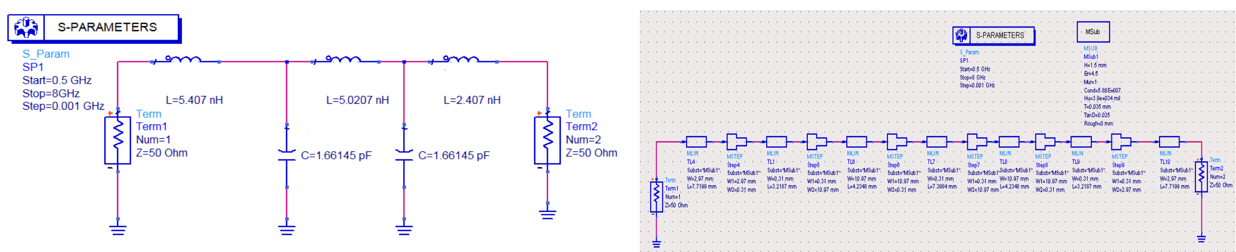
In literature, many design methodologies have been suggested to improve the low-pass filter's performance is normally not used now a days due to inherited deficiencies like slow roll off in the stop band, poor frequency response in the pass band, narrow stop band, large size [2, 3]. The miniaturizations of low pass filter circuit size are become advance in RF microwave communication applications, and it is accomplished in variety of method design. It was noticed that microwave filer circuit can be design in compact size and also will influence by wisely method technology of fabrication, such as thin film technology and defected ground structure. The new microstrip MEMS technology studied in laboratory looks promising for many reasons: first, the low cost of the substrates, standard silicon and glass, second, the simple technological process, and third the expected good performances. By using the MEMS fabrication, this low pass filter circuit can reduce to be smaller compare to previous. When the size of circuit are been reduced and increase the operating frequency and lumped element can be replaced by disturbed element, in order to help improve the simulation result performance. MEMS design technology is an extended form of traditional microelectronic IC fabrication techniques. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimetres.

There are several methods to reduce the size of microstrip low pass filters which have been reported [3–9]. One of the effective methods of size reduction is to introduce slow wave structure either in the main line [4, 5] or on the ground plane [4–6]. In [10, 14] a spiral resonator is used to replace the stepped impedance ladder network in the conventional design. The unsymmetrical stubs have also been used in [9] to design a compact filter. These methods increase the circuit complexity. The slow wave effect on the ground plane can be introduced by using the defective ground structures (DGS) [15]. The overall inductance and capacitance of the resonators can be increased using DGS and thus the compact circuit size can be achieved. The defects on the ground plane may cause unwanted radiation and it is difficult to integrate with other microwave components. To get wide stopband and sharp roll-off responses, many new methods have been proposed, such as defected ground structure (DGS) [11–13] and electromagnetic band-gap (EBG) [7, 8, 16]. In general, the etched ground of the DGS and periodic character of the EBG will cause radiation and larger size problems, respectively.

This paper is emphasized with applications of lasers in MEMS manufacture for fabricate of micorstrip low pass filter. Laser processing specifically for MEMS is currently a relatively small-scale activity and able to make the circuit size become compact.

2. MICROSTRIP LINE DESIGN TECHNIQUES

In order to design transformation to microstrip low pass filters [19], the transformations of the low pass prototype filters with normalized cut-off frequency, $W_c' = 1$ and having the source and load resistances of 1ohm are made into the desired type with the details of required source and load impedances using frequency and impedance transformations can be refer [17–20].



(a) (b)

Figure 1: (a) ADS schematic design of lumped elements Chebyshev filter. (b) Schematic microstrip circuit Chebyshev low pass filters.

Table 1: The transmitter and receiver S-parameter specification value.

Operating frequency	0.5–8 GHz
Return loss $\lvert S_{11}\rvert$	$>$ 20 dB
Insertion loss $\lvert S_{21}\rvert$	$<$ 1 dB
Stopband attenuation	$>$ 40 dB
cut off frequency (-3 dB)	2.5 GHz

3. METHODOLOGY

3.1. Fabrication on MEMS Technology-Laser Micromachining

The following sections contain an overview of these processes [21–26], together with a brief discussion of some other processes of potential importance to MEMS.

A scheme of the process flow is described in Figure 2. The fabrication process starts with the realization of a layer consisting of 1-02 µm of silicon oxide grown by wet thermal oxidation at 1000°C. The charges trapped at the silicon-oxide interface can induce a conductive channel that increase the losses on the substrates by capacitive coupling; at annealing 1000°C for 420 min in nitrogen atmosphere is performed in order to reduce the. A 1–2 µm thick layer of aluminum is then deposited by thermal evaporator at melting Point 660.37°C or boiling point 2467°C. Direct write laser micromachining, makes use of a laser beam tightly focused to a small spot which is moved over the surface of the wafer during machining. Typically direct write machining uses a laser with good beam profile and allow the beam to be focused to a small spot using simple microwave chip components and to give beam fluency at focus that is above the ablation threshold of the silicon

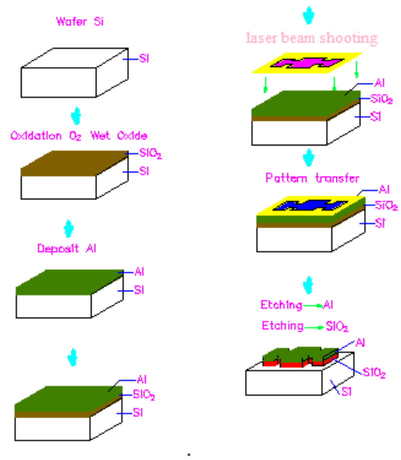


Figure 2: Laser micromachining process flow.

material. Accurate laser micromachining tends to use pulsed lasers at wavelengths where heating and melting-based surface disruption is minimal. By controlling the number of laser pulses [24, 27], and hence the total incident radiation, precise machining depths can be achieved while minimal thermal distortion occurs at the edge of the exposed region. The last process step is the release of suspended structures by removal of sacrificial resist with laser beam shooting (Figure 2). The etching process and parameters were optimized in order to remove the unwanted aluminum and oxide layer.

3.2. Process of Laser Micromachining

The setup is very simple. The laser and a detector (for measuring the intensity) set on an optical breadboard. The few attachments like a disperser and a small aperture cap which can be fixed on the detector. Firstly, the circuit can be implemented with AutoCAD software and after finish drawing, using alignment of the laser beam. This procedure can be slowly adjusting the laser in its support while checking the intensity pattern along two virtual horizontal lines at different heights on the beam cross-section. After this is done, the distance are be fixed for the detector and take intensity measurements of the beam along a horizontal line passing the point with the maximum intensity. This can be repeated with variants like with disperser alone, with cap alone, with disperser and cap. Similar readings can be taken for the vertical orientation of the laser beam too [28–30]. For calculating the beam divergence, calculate the maximum intensity of the beam, which helps in calculating the beam spot size, at different distances from the laser with the help of the optical breadboard. These can also be tabulated and the resulting calculations lead to the necessary results.

4. ADS RESULT AND SIMULATIONS

To validate whether this method was satisfactory, simulated the chebyshev microstrip circuit and measure the prototype circuit by using network analyzer and implemented on silicon substrate that had a dieletric constant of 11.9 and a thickness of 550 µm. The lumped element and microstrip line are designed by using ADS software and operating at the cut off frequency 2.5 GHz of the filter, which fulfill the design specification.

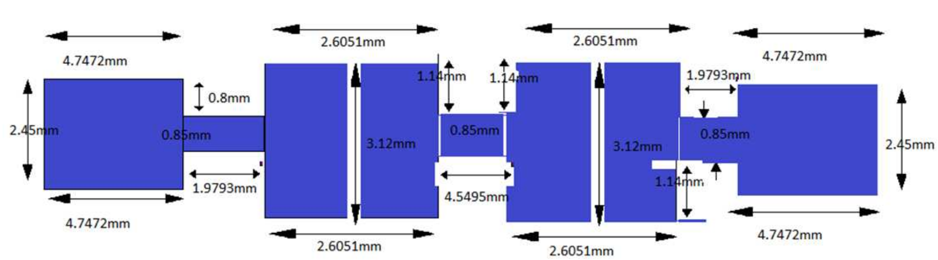


Figure 3: Schematic dimension of microstrip Chebyshev low pass filters.

Table 2: Dimension of Chebyshev microstrip low pass filter.

Section-Chebyshev-N_5	Z_c & Z_L	W (mm)	L (mm)
L_1	100	0.85	1.9793
C_2	20	3.12	2.6051
L_3	100	0.85	4.5495
C_4	20	3.12	2.6051
L_5	100	0.85	1.9793

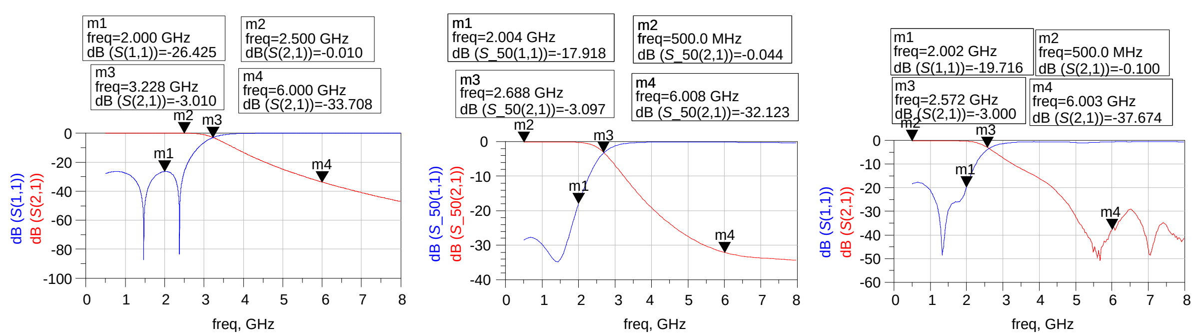
4.1. Chebyshev LPF Simulation and Measurement Result

To verify this approach whether it is feasible or not, lumped elements of all types low pass filter with 3 dB cut off frequency set at 2.5 GHz were simulated. Number of order for Chebyshev were chosen to be $N = 5$. Based on comparison between simulation and measurement as below Figure 4, the results of pratical measure and simulation have been a fairly good agreement together. Improvement can be seen in the frequency reponses of the microstrip circuit as compared to an ideal lumped element filters. It is observed that the cut off frequency are close to 2.5 GHz, meausred and simulated of low pass filters are found to be similar. The improvement in the frequency response is achieved by fabricated by using laser micromachining without changing any specifications parameters.

5. ANALYSIS AND DISCUSSION

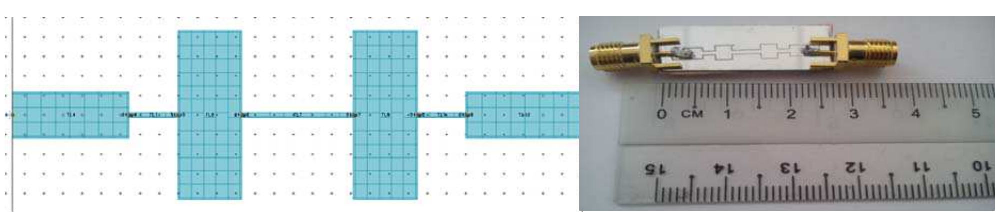
Table 3 represent the simulation result obtain from lumped elements of Chebyshev LPF by using silicon substrate. The ripples values amplitude of Chebsyev lumped element is same and located at specifications cut off point of 2.5 GHz. The return loss matching and second attenuation performances seem improves and the more unwanted frequency can be eliminated. The ripples values amplitude of all microstrip Chebsyev circuit performance is almost same and located at specifications cut off point of 2.5 GHz.

For Chebyshev microstrip Line presented that stopband attenuation frequency is seemed good where the amplitude is fall close to −40 dB. This means the attenuation are still consider enough to suppress the unwanted frequency signal. And also for the return loss matching performance



(a) (b) (c)

Figure 4: (a) Chebyshev 5^{th} order lumped element simulation result. (b) Simulation result of Chebyshev 5th order microstrip line filters. (c) Measurement result of Chebyshev 5th order microstrip line filters.



(a) (b)

Figure 5: (a).Layout of Chebsyhev microstrip low pass filter. (b) Prototype of Chebsyhev microstrip low pass filter.

Table 3: Simulation result of composite filter in ADS.

Frequency	Lumped element	Microstrip line (Simulations)	Microstrip line (Measurement)
S_{11}-return loss 20 dB	26.425 dB	17.918 dB	19.716 dB
S_{21}-insertion loss 0.5 GHz	0.010 dB	0.041 dB	0.100 dB
Cut off Frequency -3 dB (2.5 GHz)	3.228 GHz	2.688 GHz	2.572 GHz
Stopband attenuation (40 GHz)	33.708 dB	32.123 dB	37.674 dB

are close to -20 dB and means power transmitter signal able delivery to receiver. Whereas for Chebyshev microstrip line have cut off frequency close to specifications of cutoff frequency 2.5 GHz which respect to the interest frequency.

6. CONCLUSION

The microfabricated microstrip filters components presented here demonstrate the flexibility of laser micromachining for the development of microwave devices. The simulated and measured results are in reasonable agreement. The design of lumped element circuit and microstrip filter with the fringing correction factor and prototype make S-parameter cut off frequency are closed to 2.5 GHz and miniaturization of circuit are achieved. Once the microstrip circuits are fabricated by MEMS technology, size of circuit is reduced and the exact components value can be realized. The processing used in this work has made use of the unique machining properties of controlling the laser beam pulses into produce components of an integrated device. While other manufacturing processes may be used to create parts of the devices, only laser micromachining has the ability to produce all components described here. Laser micromachining has been established to operate with a broad range of materials and has the ability to cope with changes in component materials. The high quality of direct writing laser micromachining has also been validated to produce surface qualities suitable for microwave components. The method of laser micromachining of directly write structures at high speed with laser micromachining allows it to be used as a cost effective microfabrication tool are accomplished of all stages of fabrication from prototype development to large scale production. The lowpass filter will be appropriate in many RF microwave system applications because of its compactness and high performance.

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