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ABSTRACT

Increasing demand for more advanced wireless communication system, it is important to have very low-loss characteristics and low power consumption coupled with size reduction. RF MEMS (Radio Frequency Microelectromechanical Systems) is a technology which shows remarkable potential in communication systems with high quality factors and low insertion loss which includes reconfiguration. This paper emphasize the design of RF MEMS filter for X-Band frequency, a parallel coupled resonator which attenuates the frequency exactly at 8-12 GHz. X-Band is chosen which provides high spectral efficiency, lower chance for interference, less rain fade and maximum throughput. The design of RF MEMS filter is simulated using COMSOL Multiphysics through RF module. Silicon is used as a substrate material in order to enhance RF performance because of its material properties and copper used for parallel coupled resonator. The designed filter achieve insertion loss of less than -0.6dB and return loss less than -30db at center frequency 10.3 GHz. Analyses of this simulated results assures that it can give excellent mobility which enhance the performance of multiband telecommunication system.

Keywords— *Microelectromechanical systems, X-Band filter, Parallel-coupled microstrip.*

I. Introduction

Currently, microelectromechanical systems (MEMS) are in great demand in the field of defence, aerospace sectors and industries due to the benefit of size reduction without compromising on the system performance. In modern communication platform, there is a demand to have a technology solution that drive working frequencies higher, to hold larger bandwidths, and can grasp a expansive scope of group signals. The demand for minaturized wireless systems with extra functionality which enables quick development in the technology to come out with newer mechanisms with integratability into the system. Today, radio frequency microelectromechanical system (RF MEMS) technology provides a progressing solution to these challenges that currently limit the functionality of today's semiconductor technologies [1].

In this study we are concerned with Radio frequency applications of MEMS specifically with wireless communications [2]. This MEMS filter is designed for operation at X-band satisfying the implementation requirements for radar and modern multi-band communication systems [3]. With their large bandwidth, it can offer many advantages over conventional wireless connections. Advancements in the area of millimeter-wave of multimedia services and developments in satellite communications requires high-performance components.

RF MEMS capable of fullfilling the requirement by reducing the power consumption and signal loss which enhances extending battery life. The choice of selection of material depends on its type and also depends upon the device being created and the master sector in which it has to operate. Parallel coupled band pass filters are more favourable to be used for planar microstrip filters in modern microwave and wireless communication system due to its weightless,low cost and easy integration [2]. It does not suffer from dispersion and it can be integrated into a device without the additional space which makes compact wireless systems. However parallel coupled-line resonator has been discovered to be one of the most usually utilized as it has countless gains, such as easy design procedure, effortlessly obtainable design formulae, planar character, low fabrication price and elevated practicality which gives better response [4].

This paper explores the design procedure for analysis of a parallel-coupled line microstrip bandpass filter using x-band frequency. Parallel coupled resonator is multimode transmission lines which can simultaneously propagate two fundamental modes, i.e. even and odd. These two modes help to implement the filter design which eliminates undesired frequency and allow desired X-band frequency to pass. The designed filter is simulated using COMSOL Multiphysics which works with superior RF performance where the performance is characterized by using Electro-Magnetic (EM) simulations. This technique inherits to achieve efficiency and robustness of the proposed design.

Section II discusses the limitations of existing types and simulation results. Section III describes the filter design and analysis which gives the results of a proposed filter design. Section IV discusses the simulation and measurement results. Section V draws the conclusions and future development of this work.

II. Related Works

The research area for RF MEMS Filter is focused on achieving low insertion loss and in producing miniaturized transceivers. It is difficult to fabricate every design and check the performance of the filter so we do analyse the filter designs through simulation using software. Many researchers have proposed different methodologies to improve the insertion loss for the filter performance. The miniaturizations of the filter device have become advance in RF microwave communication applications, and it is accomplished in variety of method design based on its geometric structure. Furthermore, the simulation results of filter designs are optimized by software analysis. There is slight difference between each software simulation result based on design structure. Based on its complex geometric structure the accuracy of results may vary due to the approximations which you have to do in the geometry of the structure.

RF MEMS-Based Tunable Filter for X-Band Applications [2] designed 4^{th} order Tunable Bandpass Filter which tends to operate in the wireless X-Band which is designed on a microstrip platform using coupled half resonators to give a maximally flat response .The filter is designed on 635µm thick high-resistivity silicon substrate which is compatible with the new SiGe process. It is designed by following the odd and even mode impedance of the coupled line. The simulated filter achieved insertion loss of 0.7db over x- band frequency range and return loss were less than -10db throughout the operation band. The design and simulation are performed using IE3D. The simulation result depends mainly on the geometry of structure and required accuracy of the solution. However, the interface of IE3D is not quite suitable to include very fine details on the geometry of the structure.

Response Calculation of Parallel-coupled Resonator Filters by use of Synthesized Wave Digital Network [5] it explains the concept of combined wave digital/full-wave electromagnetic (EM) approach and its use to synthesize wave digital network of microstrip structure with parallel-coupled line sections. It provides a generalized S parameter description of coupled line sections, used to generate there even and odd mode characteristic impedances. It presents the design procedure and combined approach for analysis of a parallel-coupled microstrip bandpass filter. This design helps to achieve the desirable frequency throughout the operating band and eliminate the unwanted frequency. This filter design is simulated in ADS software and fabricated. In order to perform analysis of the filter design, their even and odd mode of the characteristic impedance is calculated using S-matrix. The measured S parameters help us to analyse the response characteristics of the filter.

Design of 4th Order Parallel Coupled Microstrip Bandpass Filter at Dual Frequencies of 1.8 GHz and 2.4 GHz for Wireless Application [6].The aim of this paper is to present the design technique, parameter analysis, real prototype fabrication and measurement results at dual simulation frequencies of 1.8GHz and 2.4GHz. Half wavelength long resonators and admittance inverters are used to design the filter. The filter is simulated using AWR Microwave Office software (Advanced Wave Research).

III. Proposed Method

In this paper the proposed filter is based on the Parallel coupled line resonators bandpass structure which consists of half-wavelength line resonators. They are positioned so that the adjacent resonators are parallel to every single supplementary alongside half of their length. This parallel arrangement gives moderately large coupling for a given spacing between resonators, and therefore this filter construction is chiefly convenient for constructing filters possessing a wider bandwidth as contrasted to the construction for the end –coupled microstrip filters [7]. The proposed approach can overcome the problem of integrable component and fabricating this resonator is low. A 4th order parallel coupled BPF has been designed using low pass prototype elements on a microstrip platform which give maximally flat response. Fig.3. illustrates the design structure of parallel coupled line microstrip band pass filters that use half-wavelength line resonators.

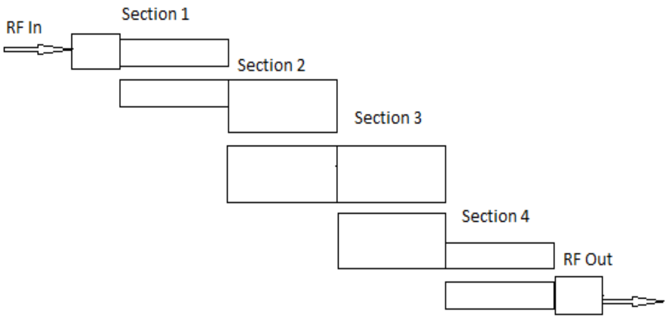

Fig.3. Top view of simulated BPF structure.

A. *Design methodology for designing BPF topology*

The design equations for the coupled lines are as follows:

The order of the filter was calculated assuming an equi-ripple (Chebyshev type 1) response with center frequency of 10.3 GHz and the passband ripple amplitude (G) of 0.5dB. The fractional bandwidth Δ = 10%. Using the standard Chebyshev model:

$$n = \frac{\cosh^{-1}\sqrt{\dfrac{(10^{L/10}-1)}{(10^{G/10}-1)}}}{\cosh^{-1}\left(\dfrac{f}{fc}\right)}$$

(1)

This gives n = 3. Now, we get the low pass prototype values from the standard Chebyshev table

TABLE I. LOW-PASS PROTOTYPE VALUES FOR N=3

g_0 = 1.0000
g_1 = 1.5963
g_2 = 1.0967
g_3= 1.5963
g_4= 1.0000

Now, we use following equations for designing admittance inverter for 1st, 2nd, 3rd & 4th pair.

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\Pi\ FBW}{2g_0g_1}} \tag{2}$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\Pi FBW}{2}\frac{1}{\sqrt{g_jg_{j+1}}} \qquad j = 1\ to\ n-1 \tag{3}$$

Where g_o, $g_{1,\ldots}g_n$ are the element of a ladder type low-pass prototype with normalized cutoff frequency.

To realize the J-inverters obtained in above equations, the even and odd mode characteristic impedances of the coupled microstrip line resonators are determined by the equation as follows.

$$\left(Z_{0e}\right)_{j,j+1} = \frac{1}{Y_0}\left[1+\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \tag{4}$$

$$\left(Z_{0O}\right)_{j,j+1} = \frac{1}{Y_0}\left[1-\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{,j+1}}{Y_0}\right)^2\right] \tag{5}$$

Obtain the even and odd mode coupled line characteristic impedances Z_{0e} and Z_{0o}. Firstly, determine equivalent single microstrip shape ratio (w/h)s. Then it can relate coupled line ratios to single line ratios.

For a single microstrip line,

$$Z_{0so} = \frac{\left(Z_{0o}\right)_{j,j+1}}{2} \tag{6}$$

$$Z_{0se} = \frac{\left(Z_{0e}\right)_{j,j+1}}{2} \tag{7}$$

Now using single line equations to find $(w/h)s_e$ and $(w/h)s_o$ from Z_{0se} and Z_{0so} [7].

For $\frac{w}{h} < 2$,

$$\frac{w}{h} = \frac{8\exp(A)}{(\exp(2A) - 2)} \tag{8}$$

where
$$A = \frac{z_C}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \tag{9}$$

From above equation $(w/h)_{se}$ and $(w/h)_{so}$ is calculated with the help of $Z0_e$ and $Z0_o$ to the single line microstrip equations. Now it comes to a point where it reach the w/h and s/h for the desired coupled edge-strip line using a family of approximate equations as following [4].

$$\frac{s}{h} = \frac{2}{\Pi}\cosh^{-1}\left[\frac{\cosh\left(\left(\frac{\Pi}{2}\right)\left(\frac{w}{h}\right)_{se}\right) + \cosh\left(\left(\frac{\Pi}{2}\right)\left(\frac{w}{h}\right)_{so}\right) - 2}{\cosh\left(\left(\frac{\Pi}{2}\right)\left(\frac{w}{h}\right)_{so}\right) - \cosh\left(\left(\frac{\Pi}{2}\right)\left(\frac{w}{h}\right)_{se}\right)}\right] \tag{10}$$

For find out (w/h)

$$\left(\frac{w}{h}\right) = \frac{1}{\Pi}\left[\cosh^{-1}\frac{1}{2}\left(\cosh\left(\frac{\Pi s}{2h}\right) - 1\right) + \left(\cosh\left(\frac{\Pi s}{2h}\right) + 1\right)\cosh\left(\left(\frac{\Pi}{2}\right)\left(\frac{w}{h}\right)_e\right) - \left(\frac{\Pi s}{2h}\right)\right] \tag{11}$$

The edge-strip transmission line by overall dielectric constant in order to is TEM Propagation. There are a number of formulas, listed for the calculation of ε_{eff}.

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1 + \frac{12h}{w}}}$$

(12)

The effective dielectric constant of edge-strip is determined & the guided wavelength of the quasi-TEM mode of edge-strip is given by equation (13) Thus the required resonator,

$$l = \frac{\lambda_g}{4} = \frac{c}{4f\sqrt{\varepsilon_{re}}} \tag{13}$$

Where $\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{re}}}$

The proposed filter is projected on silicon substrate of height 635µm. This filter demands for even and odd mode impedance characteristic impedances (Z_{0e}, Z_{0o}) of 90Ω and 26Ω suitably for the early coupled line serving, that translates to a line width of 300µm and line gap of 30µm on a 300µm silicon substrate. The subsequent couple line serving needs Z_{0e} and Z_{0o} of 62Ω and 22Ω suitably, compliant a line width of 600µm and line gap of 30µm. The last two coupled line sections are symmetrical to the first two therefore they have the alike dimensions stated earlier. The dimensions of the I/O ports are corresponding to 50Ω microstrip that might be believed as a subminiature version. Table 1 displays various design parameters along with the amount impedance of the filter construction respectively [2].

TABLE II. DIMENSIONS OF THE PROPOSED FILTER WITH THE IMPEDANCES

Parameters	Section 1	Section 2	Section 3	Section 4
Width (μm)	300	600	600	300
Spacing (μm)	30	30	30	30
Length (μm)	2500	2500	2500	2500
Even-mode Impedances (Ω)	90	62	62	90
Odd-mode Impedances (Ω)	26	22	22	26
Port impedances (Ω)	50	_	_	50

IV. SIMULATION RESULTS AND DISCUSSIONS

In this section, to check the performance of the filter design, S parameters are evaluated. With the aid of S parameter benefits we can able to investigate how RF signal interact with the device. The signal could imitate, exit other ports and dissipate via heat or electromagnetic radiation the S parameter represents each signal paths. The order of this matrix is n×n with n equaling the number of ports in the system thus, Sij represents the scattering for the j input port and the i output port [6]. The filter is simulated using COMSOL Multiphysics which is a powerful interactive environment for modeling and solving fine details of geometric structure. Fig.4. shows the parallel coupled line microstrip resonator structure which is built by using COMSOL Multiphysics for achieving desired filter response.

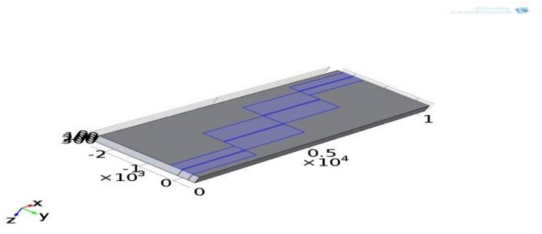

Fig.4.Geometric structure of proposed filter.

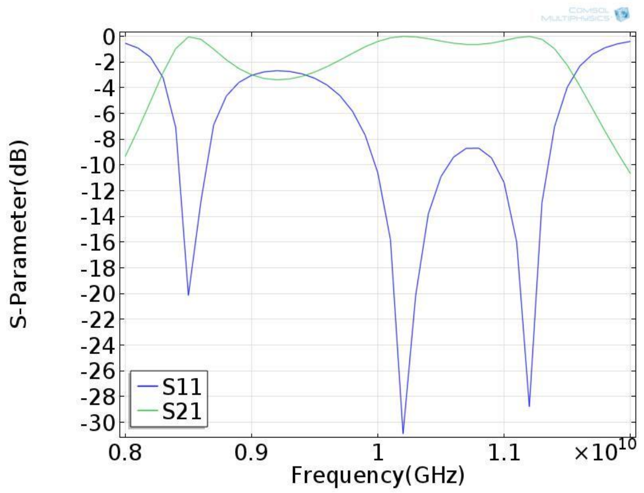

Fig.5. Frequency response of the designed filter.

The output response characteristics for and over a range of frequencies of interest are shown in Fig.5. for the designed filter, where S11 specifies return loss (i.e) the ratio of signal reflected from port 1 for an input on port 1, while S21 specifies transmission loss response at port 2 due to a signal at port 1.

The proposed filter achieves insertion loss of 0.6db and return loss less than -10db through out the operation band. A high level of signal is attenuated thus demonstrating the signal developed by the filter design.

V. Conclusion

A new parallel coupled RF MEMS filter for X-band application has been analyzed and successfully demonstrated using microstrip technology. The proposed filter achieves insertion loss less than 0.6 dB and return loss less than -30 dB at center frequency 10.3 GHz. Fig.5. graph shows low insertion loss with a high level of performance and sharp cutoff over the specified frequency range. The obtained result shows that it has achieved improved insertion loss when compared with prior works.

An examination of this filter design with fabrication feasibility has to be discussed and explored in future.

References

[1] D.V.K Sastry, "Radio Frequency Microelectromechanical Systems in Defence and Aerospace," Defence Science Journal, Vol. 59, No. 6, November 2009, pp. 568-579.

[2] Md. Fokhrul Islam, M.A. Mohd, Ali and Burhanuddin Yeop Majlis, "RF MEMS-Based Tunable Filter for X-Band Applications," Journal of Applied Sciences 8(1):189-191,2008, ISSN 1812-5654.

[3] Mukesh Kumar, Suresh kumar , "Designing of Half Wavelength Parallel- Edge Coupled Line Band Pass Filter Using HFSS " International Journal of Advanced Research in Computer Science and Software Engineering, Volume 4, Issue 8, August 2014.

[4] D.M. Pozar, Microwave Engineering, New York, Wiley, 1998.

[5] Biljana Stošić, Nebojša Dončov, Aleksandar Atanasković, "Response Calculation of Parallel-coupled Resonator Filters by use of Synthesized Wave Digital Network," IEEE, Oct 16 – 19,2013.

[6] S.Srinath, "Design of 4th Order Parallel Coupled Microstrip Bandpass Filter at Dual Frequencies of 1.8 GHz and 2.4 GHz for Wireless Application " International Journal of Innovative Research in Computer and Communication Engineering ,Vol. 2, Issue 6, June 2014.

[7] Sayantika Bhattacharjee, Debabrata Poddar, Sandeep Mukherjee, Suman Saurabh, Sudipta Das, "Design of Microstrip Parallel Coupled Band Pass Filter for Global Positioning System", Journal of Engineering, Computers and Applied sciences (JEC&AS), Vol 2, No 5, May 2013.

[8] Christopher D. Nordquist, Arnoldo Muyshondt, Michael V. Pack, Patrickson S. Finnegan," An X-Band to Ku-Band RF MEMS Switched Coplanar Strip Filter", IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 3, March 2005.

[9] Kamran Entesari, Gabriel M. Rebeiz," A Differential 4-bit 6.5–10-GHz RF MEMS Tunable Filter", IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 3, March 2005.

[10] Kamran Entesari, Gabriel M. Rebeiz," A 12–18-GHz Three-Pole RF MEMS Tunable Filter", IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 8, August 2005.

[11] Mezzannotte, P.P and R.R. Sorrentino," Electromagnetic modeling of RF MEMS structures", URSI Maastricht NL, 2002.

[12] Panaitov, G.R. Ott and N. Klein," MEMS Tunable Dielectric Resonator", Nanoscale Devices Fundamentals Applications, 2006.