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Analysis and design of RF MEMS tunable low pass filter using interdigitated CPW structures

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Abstract: This project deals with the quasi – static analysis of coplanar waveguide using conformal mapping technique and the resulting parameter are used for the design of RF MEMS filter. The electromagnetic model obtained from the conformal mapping technique is used to analyse various CPW structures and interdigitated coplanar waveguide structures. By using Conventional Coplanar Waveguide (CPW) RF MEMS filter is designed. CPW on silicon is used for RF MEMS filter design. By varying the height of the bridge, various simulations are noted. The change in thickness of the bridge varies the cut off frequency of the filter. Similarly RF MEMS filter is designed using interdigitated coplanar wave guide. Simulations results were compared for both CPW and Interdigitated CPW.

Keywords: ADS Tool, RF MEMS, CPW.

I. INTRODUCTION

A filter is an electrical network that alters the amplitude and phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component of that signal, but it will change the relative amplitudes of the various frequency components and/or their phase relationships[5][1]. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges.

Filters are networks that process signals in a frequency-dependent manner. The basic concept of a filter can be explained by examining the frequency dependent nature of the impedance of capacitors and inductors. Consider a voltage divider where the shunt leg is reactive impedance[4]. As the frequency is changed, the value of the reactive impedance changes ,and the voltage divider ratio changes. This mechanism yields the frequency dependent change in the input/output transfer function that is defined as the frequency response.

Mechanical resonators such as quartz crystals or tuning fork resonators can achieve Q-values well above 10 000. Traditional piezoelectric resonators (quartz crystals) are widely used in a frequency range up to 100 MHz. Filters based on tuning fork resonators were widely used for channel filtering in old generation analogy wire line telephone systems at frequencies around 100 kHz. Geometrical dimensions define the resonance frequency and therefore MEMS-processes are enabled to expand the concept of mechanical resonators into the GHz range. If the high Q-values can be maintained this enables one to make extremely small filters with excellent performance at low cost[1][2]. There is no clear distinction between mechanical and acoustic filters when approaching this frequency range.

II. COPLANAR WAVEGUIDE

A. *Structure of a CPW*

Conventional coplanar waveguide (CPW) consists of a single conducting track printed onto a dielectric substrate, together with a pair of return conductors, one to either side of the track[4][1]. All three conductors are on the same side of the substrate, and hence are coplanar. The return conductors are separated from the central track by a small gap, which has an unvarying width along the length of the line. Away from the central conductor, the return conductors usually extend to an indefinite but large distance, so that each is notionally a semi-infinite plane[5].

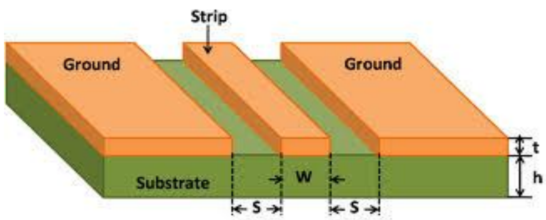

Fig. 1. Structure of the CPW

Coplanar waveguide Structure above the substrate the three conductors are located one strip central conductor with ‘W’ and other two is ground conductor is associated with ‘S’ which is gap between the two conductors. In order to draw the conventional CPW structure found an cut off frequency which is of 10GHZ and found free space wave length(λ) is 30000 µm. Guided wave length(λ_g) is the length of the Conventional CPW and which is found by using free space wavelength(λ).The substrate Thickness used in the CPW is 500 µm[4]. Silicon substrate dielectric of a CPW is 11.7 Effective dielectric of a silicon substrate is 6.35.Conventional CPW of the structure is drawn by found guided wave length, Where it is of 11900 µm. In CPW transmission loss is occur due to transmission signal at central conductor. The

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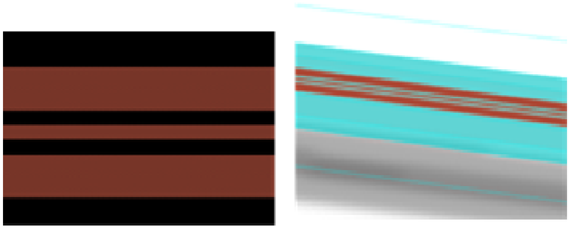
input signal is given to one end and another end output signal is taken out from the central conductor.

B. Layout of CPW

By using the guided wave length of the CPW drawn the Layout of the CPW. In the below shown figure 1.4 the layout of the CPW consists of L-Length of the CPW(λ_g=11900 µm (guided wavelength of the CPW))[5]. S-Gap between the two conductors and the gap is 100 µm and the height of the ground conductor is H = 300 µm(W+2S).



(a) (b)

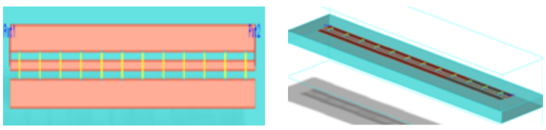
Fig. 2.(a) Layout of the CPW
(b)3-D view of the CPW

Drawn the layout of the CPW by calculating guided wavelength(λ_g) using the free space wavelength(f_c) and effective dielectric silicon substrate is 11.7 whose permittivity is 0.001[1][2].

B. *Layout of CPW using MEMS filter*

In the Layout of the CPW, draw the MEMS Filter above the cpw in order to tune the frequency. In the below shown figure 1.5 MEMS Filter is place above the CPW. The Total length of the coplanar waveguide is 11900 µm. The thickness of the Filter is 50 µm.12 bridges are placed above the CPW[3][6]. As the MEMS filter distance increase or decreases capacitance dielectric is simultaneously increase and decrease in order to tune the maximum frequency.

As the bridge distance decreases capacitance dielectric filed in the MEMS Filter increases so that characteristic impendence get decreased and tuning frequency increases and Simultaneously the distance increases capacitance dielectric filed in the MEMS Filter decreases characteristic impedance decreased and tuning frequency decreases[7].



(a) (b)

Fig. 3.(a) Layout of the CPW using MEMS filter
(b) 3-D view of the CPW using MEMS filter

III. INTERDIGITATED COPLANAR WAVEGUIDE

C. Structure of Interdigitated CPW

The interdigitated coupler (or Lange coupler) has widely been used in microwave and millimetre-wave circuits such as serial power dividers, phase shifters distributed amplifiers, single-sideband mixers, and binary phase-shift keying (BPSK) modulator[3][2][5].It has the following distinct advantages. First of all, tight coupling can be achieved with multiple coupled-lines in a single layer circuitry, which enables wideband operation and eliminates strict requirement on the spacing between strips in a conventional parallel two-line coupler[4][7].

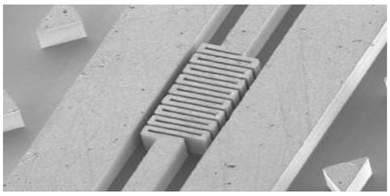


Fig. 4. Structure of Interdigitated CPW

Interdigitated coplanar waveguide similarly to an conventional CPW where the structure is varies for interdigitated in length, area due the transmission signal is passing through transmission line[2][1][3].Two-conductor transmission line such as parallel line (ladder line), coaxial cable, strapline, and micro strip. Some sources also refer to waveguide, dielectric waveguide, and even optical fiber as transmission line, however these lines require different analytical techniques[7].

D. Layout of Interdigitated CPW

By using the guided wavelength of the CPW drawn the Layout of the interdigitated CPW. In the below shown figure 1.6 the layout of the interdigitated CPW consists of L-Length of the CPW(λ_g=3970 µm (guided wavelength of the CPW)). S-Gap between the two conductors and the gap is 100 µm and the height of the ground conductor is H = 300 µm[5].Zigzag length of central conductor is 50 µm. The gap between zigzag length is 1000 µm.

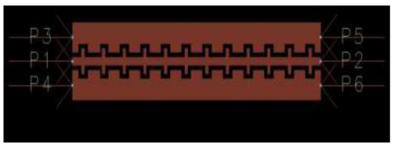


Fig. 5. Layout of Interdigitated CPW

E. Design 1-Interdigitated CPW Filter 1

In the Layout of the CPW, draw the MEMS Filter above the interdigitated cpw in order to tune the frequency. In the below shown figure 1.7 MEMS Filter is place above the interdigitated CPW[6]. The Total length of the interdigitated coplanar waveguide is 3790 µm. The thickness of the Filter width is 1000µm and length is 50 µm.12 bridges are placed above the interdigitated CPW. As the MEMS filter distance increase or decreases capacitance dielectric is simultaneously increase and decrease in order to tune the maximum frequency[3].

As the bridge distance decreases capacitance dielectric filed in the MEMS Filter increases so that characteristic impendence get decreased and tuning frequency increases and Simultaneously the distance increases capacitance

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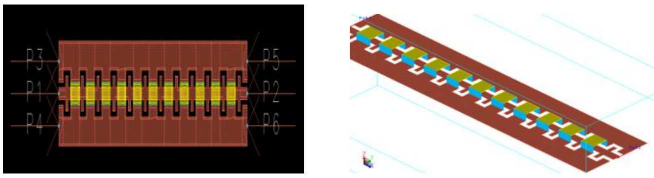
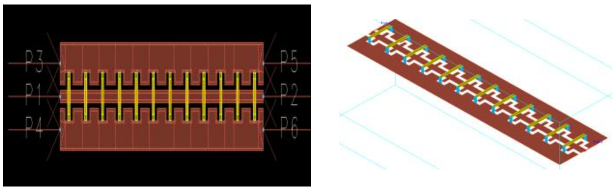


(a) (b)

Fig. 6.(a) Layout of the interdigitated CPW for filter 1
(b) 3-D view of the Interdigitated CPW for filter 1

F. Design 2-Interdigitated CPW Filter

In the Layout of the CPW, draw the MEMS Filter above the interdigitated cpw in order to tune the frequency. In the below shown figure 1.8 MEMS Filter is place above the interdigitated CPW[6][7]. The Total length of the interdigitated coplanar waveguide is 3790 µm. The thickness of the Filter width is 50µm and length is 100µm.12 bridges are placed above the interdigitated CPW. As the MEMS filter distance increase or decreases capacitance dielectric is simultaneously increase and decrease in order to tune the maximum frequency[2].



(a) (b)

Fig. 7.(a) Layout of the interdigitated CPW for filter 2
(b) 3-D view of the Interdigitated CPW for filter 2

IV. SIMULATION RESULTS

The RF MEMS Filter design is simulated using Agilent Advanced Design System 2009.The simulation results in losses are obtained in the form of S-parameters[5].

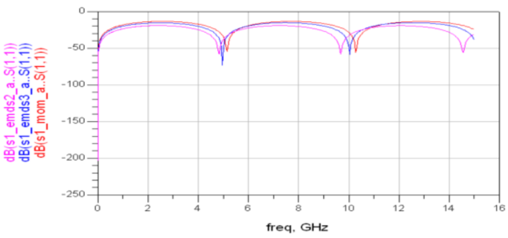


Fig.8. Conventional Coplanar waveguide for return loss

From above Figure 8,the return loss achieved is -55.631 dB at 10GHZ with no MEMS bridge placed on CPW line. When 12 MEMS bridges are placed at 3 µm heights the return loss obtained is -58.75 dB at 10.04 GHZ which is designed resonant frequency. When MEMS bridge is actuated, the bridge positions decreased to 2 µwhere the return loss is obtained to be -57.961db at 9.68 GHZ. The simulation results shows a tuning of frequency from 10.04GHZ to 9.68 GHZ.

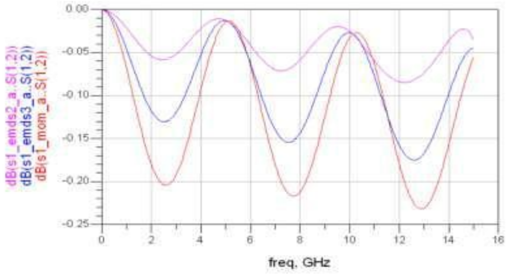


Fig .9. Conventional coplanar waveguide for insertion loss

In Figure 9 shows the simulation of insertion loss having -0.027db under no bridge condition and -0.021 dB at 3 µm and 2 µrespectively

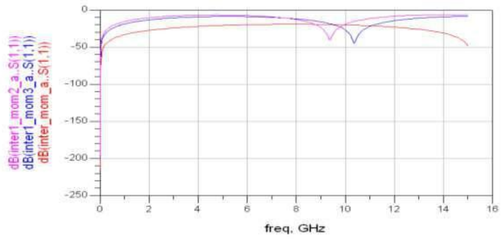


Fig.10. Interdigitated CPW of various thickness for filter 1(return loss)

In the above shown figure 10,output of the interdigitated coplanar waveguide is discussed for various thickness using MEMS filter and without using the MEMS Filter[3].The thickness of the MEMS filter is varied for 3 µm and 2 µMs(1,1) Represents the Return Loss and it is simulated using Agilent Advanced Design System 2003.

Without the bridge at 10.65GHZ the tunable frequency is -49.631.3 µm thickness of the bridge at 10.35 GHZ the tunable frequency is -44.954 and 2µm thickness of the bridge at 9.735 GHZ the tunable frequency is -40.647[7].

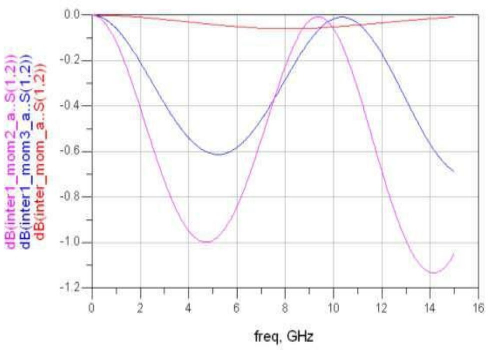


Fig.11.Interdigitated CPW of various thickness for filter 1(insertion loss)

In the above shown figure 11,output of the interdigitated coplanar waveguide is discussed for various thickness using MEMS filter and without using the MEMS Filter[7].The thickness of the MEMS filter is varied for 3 µm and 2 µms (1,2) Represents the Insertion Loss and it is simulated using Agilent Advanced Design System 2009.Without the bridge the insertion loss is -0.015 dB at 3 µm thickness of the bridge the loss is -0.009 dB and 2 µm thickness of the bridge the loss is -0.008 db.

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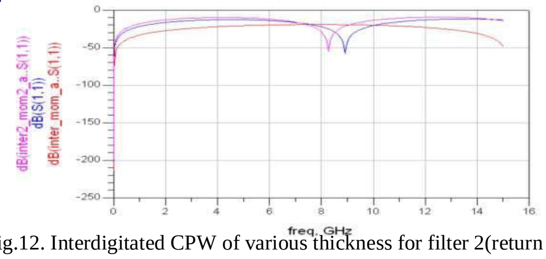

Fig.12. Interdigitated CPW of various thickness for filter 2(return loss)

In the above shown figure 12,output of the interdigitated coplanar waveguide is discussed for various thickness using MEMS filter and without using the MEMS Filter[7][3].The thickness of the MEMS filter is varied for 3 µm and 2 µms(1,1) Represents the Return Loss and it is simulate by using Agilent Advanced Design System[1]. Without the bridge at 10.55GHZ the tunable frequency is -.63.12.3µm thickness of the bridge at 8.906 GHZ the tunable frequency is -57.93 and 2 µm thickness of the bridge at 8.281 GHz the tunable frequency is -54.912.

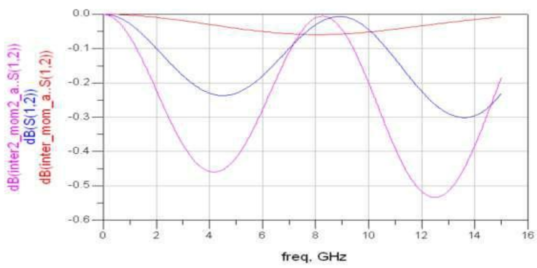

Fig.13. Interdigitated CPW of various thickness for filter 2(insertion loss)

In the above shown figure 13,output of the interdigitated coplanar waveguide is discussed for various thickness using MEMS filter and without using the MEMS Filter. The thickness of the MEMS filter is varied for 3 µm and 2 µms(1,2) Represents the Insertion Loss and it is simulated using Agilent Advanced Design System 2009.Without the bridge the insertion loss is -0.010 dB at 3 µm thickness of the bridge the loss is -0.007 dB and 2 µm thickness of the bridge the loss is -0.006 db.

TABLE 1
COMPARISON OF INTERDIGITATED CPW DESIGN 1 AND DESIGN 2

Comparison of Interdigitated CPW for design1		
Parameter	Return Loss	Insertion Loss
Without bridge	-49.631	-0.015db
With bridge (3 µm thickness)	-44.952	-0.009 dB
With bridge (2 µm thickness)	-40.647	-0.008 dB
Comparison of Interdigitated CPW for design 2		
Parameter	Return Loss	Insertion Loss
Without bridge	-59.12	-0.009db
With bridge (3 µm thickness)	-57.93	-0.007 dB
With bridge (2 µm thickness)	-54.912	-0.006 dB

V. CONCLUSION

Both the design parameters are same but the structure is varied for interdigitated CPW and is reduced to 2/3 of the conventional CPW.RF MEMS filter is designed for both conventional and interdigitated CPW in order to tune the frequency[1][2].The bridge is placed above the structure where the distance varied, characteristic impedance varied and tuned the maximum frequency. As for the MEMS filter place above the CPW the return loss and insertion loss can be achieved. For conventional CPW[3][5],return loss without the bridge the tuning frequency is high at 10.27GHZ and at 2 µm thickness of the bridge the tuning frequency is 9.68GHZ so the tuning range of the +conventional CPW is reduced to 0.59GHZ and similarly without the bridge the insertion loss is -0.027db and at 2 µm thickness the loss is reduced to -0.021db.For interdigitated the 2 design of filters place above the CPW. One filter design is large width and small length. In that return loss without the bridge the tuning frequency is high at 10.65GHZ and at 2 µm thickness of the bridge the tuning frequency is 9.735 GHZ so the tuning range of the interdigitated CPW is reduced to 0.915GHZ and similarly without the bridge the insertion loss is - 0.015db and at 2 µm thickness the loss is reduced to -0.008 db. Other filter design is small width and large length. In that return loss without the bridge the tuning 47 frequency is high at 8.906GHZ and at 2 µm thickness of the bridge the tuning frequency is 8.281 GHZ so the tuning range of the interdigitated CPW is reduced to 0.625 and similarly without the bridge the insertion loss is -0.007db and at 2 µm thickness the loss is reduced to -0.006 db. In interdigitated coplanar waveguide as compared to both designs, the design 2 is better than design 1 where in design 2 both return loss and insertion loss is reduced. So the interdigitated filter design 2 is comparatively both area and tuning frequency is reduced than conventional CPW.

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REFERENCES

[1] A. Takacs, D. Vasilache, C. Tibeica, D. Neculoiu, June 2005 " New Topology of RF MEMS Shunt Switch for Reconfigurable Systems Applications", Proceedings of the 37th European microwave conference.
[2] Erli Chen and Stephen Y. Chou, June 1997 "Characteristicsof Coplanar Transmission Lines on Multilayer Substrates: Modeling and Experiments" IEEE Transaction of microwave theory and techniques.
[3] M.D.FokhrulIslam, .Mohd. Ali,B.Y.Majlis and Nowshad Amin, December 2008"RF MEMS filter design ,simulation and fabrication process", 5th International Conference on Electrical and

Computer Engineering.

[4] P.Thiruvalaselvan, S.Raghavan and S.Suganthi Jan 2009"A CAD Neural Model for Quasi –Static Analysis of CPW synthesis" International journal of microwave and optical technology, vol 4.

[5] Rizwan Masood and S.A.Mohsin, Aug 2012"Equivalent Network Extraction of a Coplanar Waveguide". PIERS proceedings, Mascow, Russia.

[6] Young K.Song,ChinC.Lee ,September 2007 "Topology Bandpass filters in Coplanar Striplines",Electrical Engineering and Computer Science, University of California.

[7] YuLiu,AndreaBorgioli,AmitS.Nagra,Robert A. York, March 2001 "Distributed MEMS Transmission Lines for Tunable Filter.