Implementation of a tunable coplanar Filter

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Abstract —**This paper presents the implementation of a 34GHz tunable CPW filter. An original excitation structure has been used. The filter has been simulated achieving 9% fractional bandwidth, insertion losses of 4 dB, return losses better than 15 dB and 3% tunability.**

I. INTRODUCTION

With the increasing complexity of high frequency systems, CPW has provided an attractive alternative to conventional microstrip lines. Its uniplanar structure, insensibility to the substrate thickness and the readiness to realize shunt and serie connections and integration of active devices via the flip-chip technology makes the CPW technology very interesting as the density of interconnection increases. Despite this, relatively little has been done on coplanar filters, especially at high frequencies [1]-[5].

This paper describes a 30 GHz tunable two pole coplanar filter with 9% relative bandwidth. Its design is very simple as it consists of two shunted quarter wavelength resonators feed by smaller coplanar lines [6] which is an original excitation system to couple the energy at the input-output. The tunability is obtained by putting four MEMS capacitors at the ends of the resonators.

First we will see how does the tunable filter work and how it has been designed. Then, the experimental filter will be presented with its simulation results. A 3% tuning band has been achieved with low loss.

II. FILTER DESIGN

The filter which has been previously presented in [7] is made of two quarter wavelength resonators put in front of each other and capacitively coupled. A two part coplanar line excites them. The first section is a 50Ω feeding line. The width and length of the second one (w_2, l_2) are optimized to obtain the right external quality factor Qext. The coupling between the resonator and the input line is realized by mutual inductance since the shape of their magnetic field are very close as shown in figure 1.

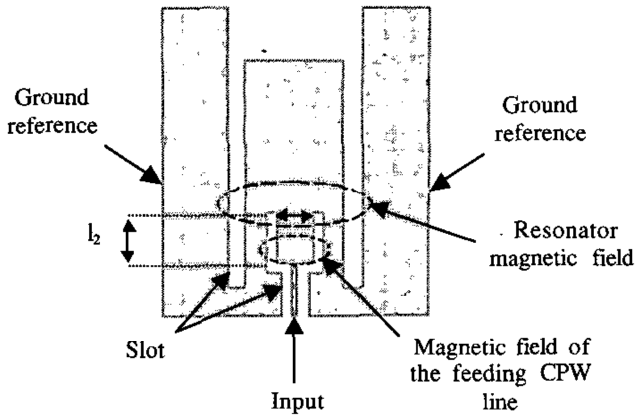

Fig. 1. Coupling between the feeding lines and the resonator

This filter can be modeled in a equivalent circuit in lumped element has shown in figure 2. The excitations are made with inductors and the inter resonator coupling with a capacitor. The MEMS capacitors have been added to the equivalent scheme and allows to perform tuning of the structure.

III. TUNABLE TWO POLE FILTER

This filter has been made tunable by adding four MEMS varactors at appropriate positions to the resonators. A photograph of the tunable filter is available on figure 3 and the dimensions on figure 5 and table I. Four MEMS cantilevers are anchored in the central conductor of the coplanar line. The upper electrodes are 2μm above the ground reference plane. By applying a biasing voltage between the central conductor and the ground reference plane, the upper electrodes are deflected down, modifying the capacitance value between them and the ground plane. This capacitance difference changes the resonant frequency of the resonators allowing to make the filter tunable. The MEMS varactors are used on the first third of their initial eight. Thus, the capacitance variation is continuous but limited. In theory, the capacitance variation can be 50% from its nominal value, but it is well known that the variation is much less in practice, about 30 %.

The presence of the varactors must modify the resonant frequency of the resonators without changing too much the inter resonator coupling coefficient as it can be seen on the equivalent circuit in lumped elements on figure 2.

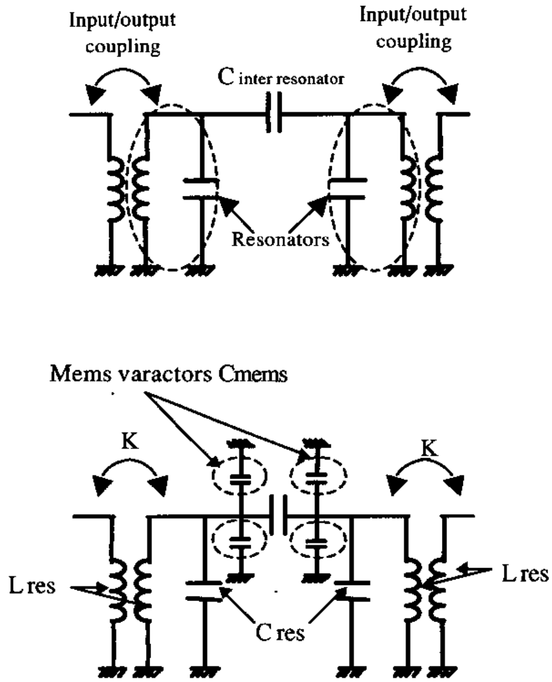

Fig 2. Equivalent circuit of the tunable filter without and with MEMS

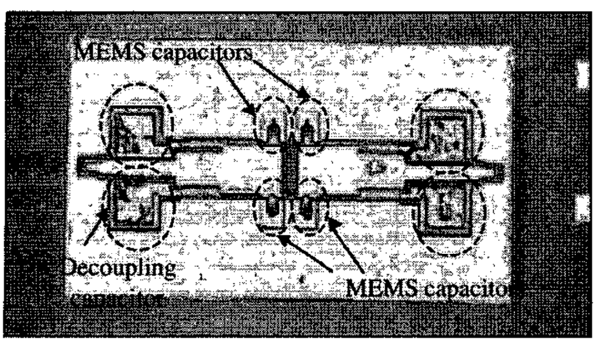

Fig. 3. Photograph of the fabricated device

The varactors are actuated through a set of decoupling capacitors that are fully integrated on the filter. This allows to avoid the integration of resistive feeding network, that would add loss to the circuit. These capacitors are necessary to prevent the continuous voltage from reaching the ground conductors which would hinder the MEMS biasing. These capacitors must be large enough to present a very low impedance at 30 GHz.

TABLE I
VALUES OF THE LUMPED ELEMENTS

Lres	0.165nH
Cres	77.9fF
K	0.37
C inter resonator	11fF
C mems (up-state)	25fF

The filter has been simulated, with Agilent ADS. A 7% maximum tuning band can be achieved, as shown in fig 4, assuming that the varactors have a 30% variation. The final layout has been simulated with Momentum and the filter has been fabricated.

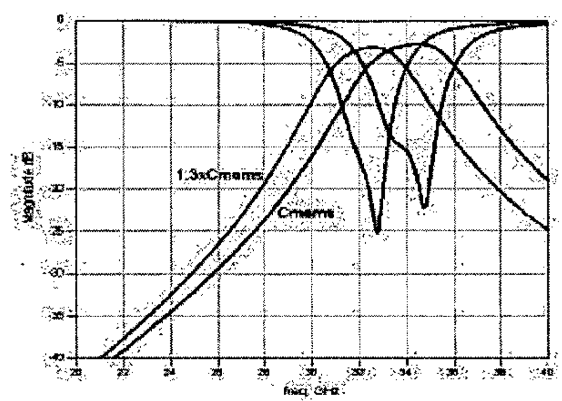

Fig 4. Simulation results of the tunable filter

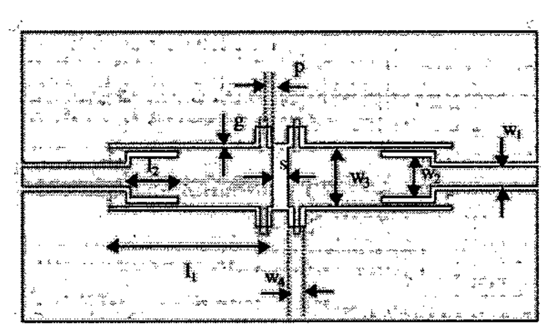

Fig 5. Layout and dimensions of the tunable filter

IV. FABRICATION

The circuit has been fabricated on a 525 μm thick fused silica substrate (εr=3.8) that provides low substrate losses. A 0.8μm thick gold layer is deposited and etched to design the coplanar lines. Then a 0.3μm alumina layer is deposited using a pulsed laser ablation deposition. This layer is used to prevent metal to metal contact between the upper electrodes and the ground reference plane and also to realize the decoupling capacitors. Then a 2μm thick sacrificial layer is deposited and patterned. It will be removed during the last MEMS fabrication step. The upper electrode metal layer is made of a 50/1500 Å titanium/gold electroplated to 2μm. The last fabrication step consists of removing the sacrificial layer, and to dry the structure with a critical point dryer to release the upper electrode.

V. MEASUREMENTS

Measurements were taken using an HP 8510C and a cascade probe station. The filter is biased through the RF probes. A SOLT calibration was used and the presented measurements are shown on figure 6.

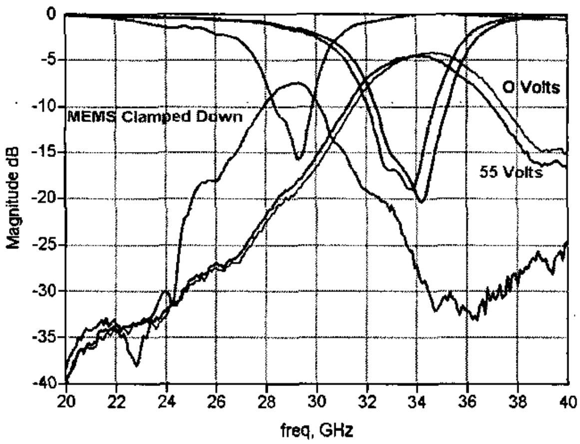

Fig 6. Measurements

A 9% relative bandwidth has been measured with 4dB insertion losses and 16dB return losses. The center frequency can be shifted by 1GHz around 34 GHz in the analog region of the varactors, the insertion loss are still at 4dB, and return loss are better than 15dB. The MEMS cantilevers pull down voltage is about 58Volts, and when MEMS are pulled down, the resulting response of the filter is shown on the same figure. It can be seen that losses are increased by 3dB, but matching remains correct and the corresponding tuning range is about 15%. Loss increase is linked with bandwidth contraction down to about 5%, from 10% initially.

V. CONCLUSION

This study focuses on a new design for a tunable 34 GHz tunable bandpass filter. It has been done in two steps: first the conception of the simple filter with an original coupling technique, then the addition of the MEMS capacitors to make it tunable. A 9% relative bandwidth and a 3% tuning band have been achieved.

TABLE II

VALUES OF THE DIFFERENT DIMENSIONS OF THE CIRCUIT

l_1	1045μm
l_2	390μm
w_1	300μm
w_2	400μm
w_3	110μm
w_4	120μm
s	150μm
p	60μm
MEMS length	190μm
MEMS width	50μm
g (slot gaps)	30μm

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