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높은 Q값을 가지는 MMIC 전송선을 이용한 밀리미터파 필터

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Millimeter Wave Filtres using a high Q MMIC Transmission Line

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Abstract - In this paper we discuss the design and fabrication of two millimeter wave filters, in bandpass and bandstop topologies for wireless communications applications. The filters are made using a high Q MMIC transmission line, which consists of a 100 micrometers tall, surface micromachined, air filled inverted microstrip structure on a quartz substrate, made by using a JSR THB-151 N negative photoresist sacrificial layer mold and electroplating technology. The filter topologies include a new, very compact, four pole, cross-coupled filter, that presents a single transmission zero at the lower side of the passband, which provides a very sharp out of passband rejection at this region.

1. Introduction

Low loss monolithic microwave integrated circuit (MMIC) transmission lines are of big interest for low cost and high production volume integrated circuits, where active and passive components can be integrated on a single chip. Our particular interest here is on low loss transmission line structures suitable for microwave filters, where high resonator unloaded quality factors (Qo) are always desirable. Low loss coplanar transmission lines have been presented, where loss reduction can be achieved by using overhanging wide center conductors [1], or by removing the material between conductors [2]. A 10 micrometers high, dielectric post suspended microstrip can be found in [3]. In this paper, we also focus on a low loss microstrip structure, where we propose the use of a 100 micrometers high, inverted microstrip transmission line in order to obtain larger center conductor widths, for a given impedance compared with [3], in an effort to reduce the conductor losses, and increase the overall resonator Qo. The proposed transmission line, also provides a 100 micrometers tall air cavity, allowing for most of the electromagnetic field to be contained in this region, also to preserve a high Qo. This paper contains the design of two filter topologies using the proposed inverted microstrip structure. The first design is a compact, four pole cross-coupled filter, with a 15% fractional bandwidth (FBW), exhibiting a single transmission zero at the lower side of the passband. The second design is a three pole, bandstop filter with a 5% FBW. The photograph of the micromachined inverted microstrip presented in this paper is shown in figure 1.

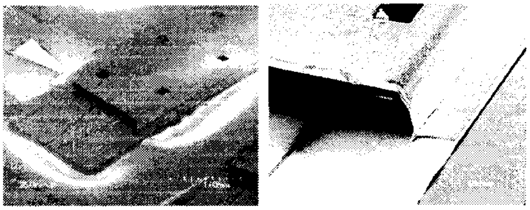
(a) (b)

Figure 1. Photograph of the inverted microstrip (a) complete structure, (b) side wall close up

2. Coplanar waveguide to inverted microstrip transition design

In order to interface the inverted microstrip structure for on wafer probing, the tapered coplanar waveguide (CPW) shown in figure 2 has been designed. The design consists of a 50 ohm CPW pad for probing, that converts to a 50 ohm inverted microstrip, through a CPW taper. The tapered CPW ends 100 micrometers inside the surface micromachined ground plane, minimizing radiation losses at the transition, while providing good impedance matching.

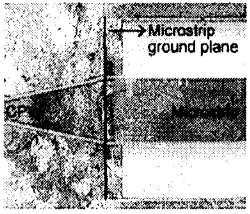

Figure 2. Photograph of the CPW-to-Inverted microstrip transition (ground plane removed).

The tapered CPW ground plane, makes an abrupt transition in a straight line to merge perpendicularly with the sides of the suspended microstrip ground plane, at substrate level, in order to launch a microstrip mode down to the filters. This transition is destined to be placed at the input and output ports of the filters presented in section 3. The measured response of the transition in a back to back configuration, with a total probe-pad to probe-pad length of 2.9mm is shown in figure 3. Here we used pyrex glass for the experiment, but for the filters we intend to use quartz as the substrate.

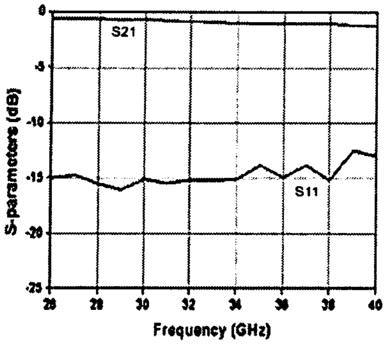

Figure 3. CPW-to-inverted microstrip transition response

3. Filter design

In this section we briefly present two filter topologies that we intend to make with the proposed inverted microstrip line. The filters use short circuited quarter wavelength resonators, where the short circuit is achieved by the junction of the sidewall of the suspended microstrip ground plane, and the quarter wavelength resonators at the substrate. The first filter is a 15% FBW, four pole, cross-coupled resonator filter, chosen to have a quasi-elliptic response, with a 0.1 dB passband ripple. The second filter is a 5% FBW, three pole bandstop filter, chosen to have a Chebyshev response, and a 0.1 dB passband ripple. The general filter theory involved in the design of these filters, can be found in [4].

3.1 Bandpass filter

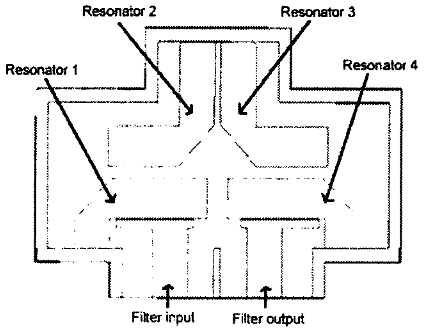

Figure 4, Cross-coupled bandpass filter topology

We have designed a new cross-coupled filter topology with asymmetric frequency response, where traditionally this type of response has been achieved by using configurations of three resonators, or trisection filters [5]. This filter is useful for applications where a high rejection is desired only at the lower side of the passband, and few or non rejection required on the upper side of the passband. Figure 4, shows the proposed filter configuration. The equivalent circuit of the cross-coupled filter is shown in figure 5, where the J's between resonators are admittance inverters [4].

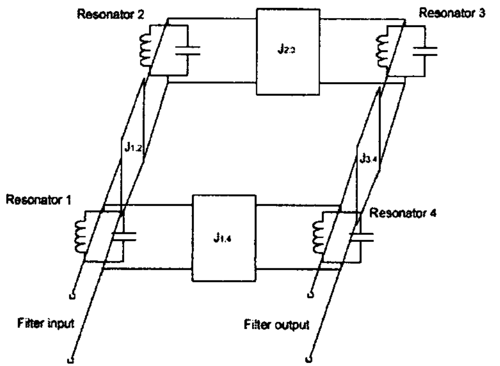

Figure 5. Equivalent circuit of the cross-coupled resonator filter

The computed response using [6], for the filter assuming lossless transmission lines is shown in figure 6.

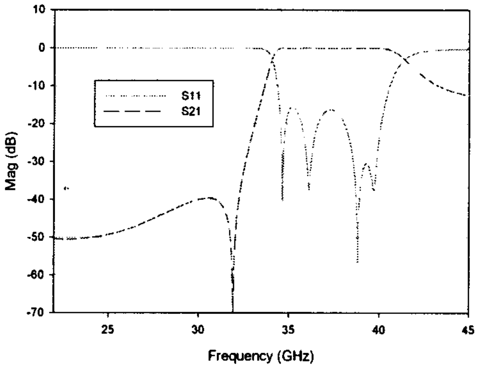

Figure 6. Bandpass filter response

3.2 Bandstop filter

In this section we describe the design of the three pole, 5% FBW bandstop filter shown in figure 7. Where the resonators are electrically coupled to the transmission line, which goes from the input, to the output of the filter.

The computed response using [6], for the bandstop filter, considering lossless inverted microstrip transmission lines, using three shunt resonators is shown in figure 8.

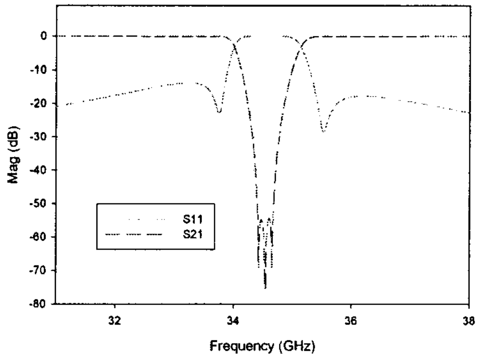

Figure 7. Bandstop filter topology

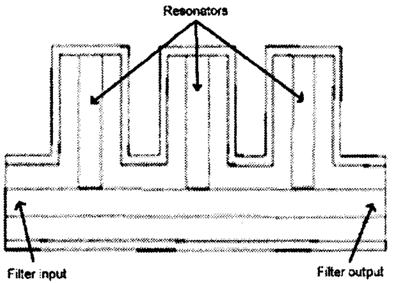

Figure 8. Bandstop filter response

4. Fabrication process

Although SU-8 has an advantage for the fabrication of high aspect ratio structures [7], new resists have been continuously experimented to replace the SU-8 because of its difficulty when removing [8, 9]. JSR THB series resists are good candidates, because they are easily stripped off, and can produce good vertical sidewalls [8, 9]. This paper proposes a new process using THB-151N to obtain a thick sacrificial layer, used to obtain the 100 micrometers airgap for the inverted microstrip ground plane (Fig.9).

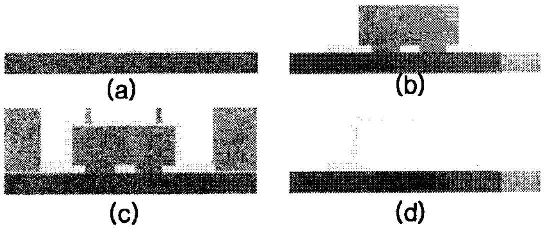

Fig. 9. Fabrication process; (a) electroplated signal line, (b) sacrificial layer patterning & seed deposition, (c) 2nd mold fabrication & Au electroplating, (d) sacrificial layer removing and structure completion

To avoid stiction caused by edge beads, between wafer and photomask during photomask alignment, THB-151N was coated and baked for 30 minutes. This is 3 to 6 times longer than the condition supplied by the vendor, which is used for a stepper system. Exposure energy of 2000 mJ/cm^2 was applied in a soft contact mode. A metal seed layer was evaporated onto the sacrificial layer, to form a good conformal deposition on the sidewalls and top surface of the resist. After this, a 160 micrometers high second mold was formed with the same resist to completely cover the sacrificial layer. Then Au was electroplated to form the suspended ground plane anchored at the substrate. Now when mold and seed layers are removed, these leave ash holes on the top surface of the ground plane for sacrificial layer removal. Finally sacrificial layer removal was performed by O_2 plasma ashing. The final fabricated inverted microstrip is shown in figure 1.

5. Conclusions

In this paper we have proposed the use of a MMIC high Q, micromachined transmission line for millimeter wave filter applications. The fabrication process used to obtain the 100 micrometers inverted microstrip ground plane has been presented. A CPW-to-inverted microstrip transition interface has been designed and tested for on-wafer probing. A four pole cross-coupled filter topology having a single transmission zero, and a three pole bandstop filter have been discussed. Our further work includes extracting the Qo of a resonator and experimental work with the filters.

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