Coaxial Quasi-elliptic Filter Using a Suspended Resonator and Vertically Stacked Coaxial Lines

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Abstract— In this paper a four pole quasi-elliptic filter at X-band is presented. The filter is composed of two vertically stacked rectangular coaxial lines, where one pair of resonators is placed on the lower coaxial line and another pair is located on the upper line. Coupling between coaxial lines is achieved through an iris in the common coaxial ground plane. The filter has been designed at 9.1 GHz with a 4% fractional bandwidth. Two transmission zeros located at the sides of the passband have been successfully achieved with the proposed filter topology. A measured insertion loss of 1.7 dB has been obtained.

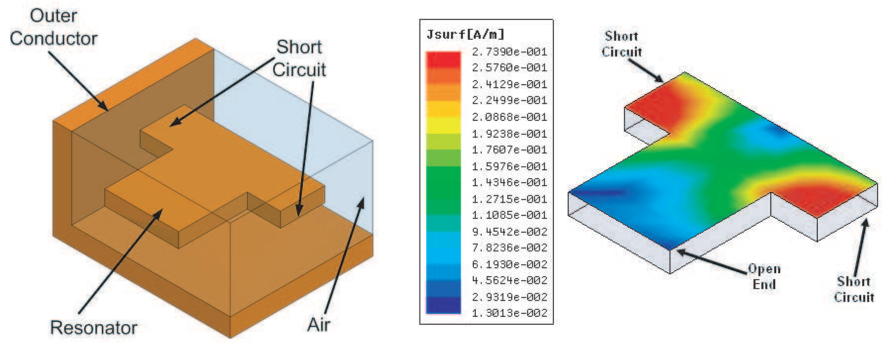
1. INTRODUCTION

The rapid advance in wireless communications has led to the development of high performance filters, with high selectivity and good out of band rejection, including device miniaturization. Introducing transmission zeros on a bandpass filter response can achieve high selectivity with good out of band rejections. Commonly coaxial-combline cavity filters with transmission zeros have been designed by means of coupling probes embedded in the filter fixture [1], also the use of extra cavities or small metal plates among the resonators [2, 3] have been used. The structure presented in this paper uses a suspended resonator in different coupling arrangements to produce electric, magnetic and mixed couplings, enabling quasi-elliptic function approximation or flat group delay responses, instead of using extra coupling probes, extra cavities or folded structures.

The use of narrowband filters between amplifier stages with insertion loss (< 2 dB) can be tolerated, because compact size and low fabrication costs are more important to keep the filter competitive [4]. The proposed structure was designed at 9.1 GHz where only few works can be found, since most of combline and interdigital filters are designed between 1 and 2 GHz. The introduction of cross-couplings has been used to obtain a pair of transmission zeros on the sides of the passband. The unloaded quality factor of a single resonator was measured and has been found to fall in-between the high Q obtained through optimized conventional coaxial-combline designs and interdigital or microstrip-combline filters. The planar implementation of the filter (made by 9 stacked planar metal layers) allows scaling the designs to the millimeter wave frequencies range, using micromachined structures [5].

2. SUSPENDED COAXIAL RESONATOR

This section presents a quarter wavelength resonator suspended by short circuits inside an air filled rectangular coaxial cable, shown in Fig. 1(a). The resonator has the maximum magnetic field density next to the short circuited stubs, and the maximum electric field at the opposite side, the surface current distribution at the resonant frequency of 9.1 GHz is plotted in Fig. 1(b). Electric, magnetic and mixed couplings can be obtained by choosing adequate coupled resonator configurations. By placing the two short circuited sides of the resonator facing each other, a magnetic coupling can be obtained. Electric coupling can be attained by placing the open end of the resonators facing each other. The responses of the electric and magnetic coupling arrangements are out of phase and have been used to produce the quasi-elliptic filter presented in this paper. Mixed couplings have been obtained by placing resonators on different coaxial lines, coupled by an iris on the common coaxial ground plane between them.



(a) (b)

Figure 1: Suspended quarter wavelength resonator. (a) Schematic of the quarter wavelength resonator (side and top walls removed for clarity). (b) Surface current distribution at the resonant frequency of 9.1 GHz.

3. NARROWBAND QUASI-ELLIPTIC COAXIAL FILTER USING VERTICALLY STACKED COAXIAL LINES

This filter was designed using two vertically stacked coaxial cables, as illustrated in Fig. 2, where two resonators are placed on the upper coaxial line, and two others on the lower line, along with the feed lines that provide the input/output to the device. The entire topology is formed by nine conductive layers stacked and compressed together to obtain the two coaxial transmission lines. An iris in the common coaxial ground plane allows the cross coupling arrangement between resonators.

The design procedure for this filter follows the methodology provided in [6], which consists in calculating the coupling coefficients between resonators (K_{ij}) and the external quality factor (Q_e), achieved by full wave simulations using HFSS. The equations to obtain the theoretical couplings between resonators and the external quality factor can be found in [6]. The design data and parameters used for this filter are summarized in Table 1, which contains the lowpass quasi-elliptic element g values, the required K_{ij} and Q_e for the design. The filter was designed at 9.1 GHz with a 0.01 dB passband ripple and a 4% fractional bandwidth, having a quasi-elliptic response.

After obtaining the optimum spacing between resonators and feed lines, the filter can be realized. Overall dimensions of the filter are $29.8 \times 48.7 \times 20\,\mathrm{mm}^3$. Simulation and measurements of the filter are shown in Fig. 3. This simulation assumes the effect of layer misalignment, where 12 simulations

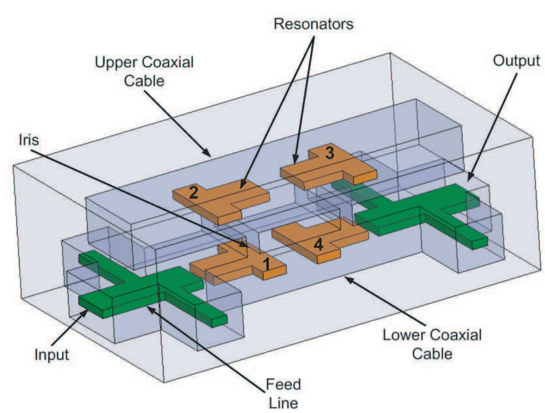


Figure 2: Quasi-elliptic filter topology using vertically adjacent coaxial lines.

Table 1: Quasi-elliptic filter design parameters.

Lowpass filter element g values for $\Omega_d = 2.00$			
$g_1 = 0.95449$	$g_2 = 1.38235$	$J_1 = -0.16271$	$J_2 = 1.06062$
Q_e and K_{ij}			
$Q_e = 23.862$	$K_{12} = K_{34} = 0.0348$	$K_{23} = 0.0307$	$K_{14} = -6.8 \times 10^{-3}$

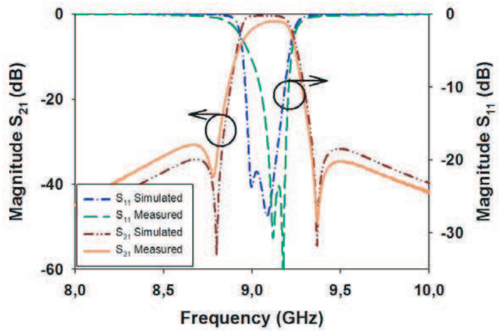


Figure 3: Simulated and measured results for the quasi-elliptic filter implemented on stacked coaxial lines.

have been done displacing the layers that compose the filter arbitrarily using values ranging from 100 to 500 µm, and one of them was arbitrarily selected to be included in Fig. 3. The 12 simulations showed a reduction in filter bandwidth due to the change in coupling coefficients caused by the overlapping of air spacing layers with the main central coaxial conductor. This causes a reduction in coupling coefficients and results in narrower bandwidths. The variations between simulation and measurement results can be attributed to the misalignment of the stacked coaxial layers, fabrication tolerances and the effect of using eight brass tuning screws to obtain the measured filter response. The measured bandwidth decreased from 4% considered for the design to 2.88% experimentally, the simulation with misaligned layers showed a bandwidth of 3.13%. The transmission zero on each side of the passband was successfully achieved using the proposed vertically integrated coaxial filter.

4. CONCLUSIONS

A new type of narrowband quasi-elliptic filter using vertically stacked coaxial lines has been presented. The filter uses cross-couplings to produce a quasi-elliptic response with a pair of transmission zeros, using an inline suspended resonator. The filter implementation using planar machined metal layers allows scaling the design to millimeter wave frequencies using micromachined techniques.

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