MINIATURE BANDPASS FILTER WITH A WIDE STOPBAND UP TO 40F_0

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ABSTRACT: *A 243-MHz narrowband filter with high selectivity performance has been designed. The filter comprises two electromagnetically coupled quasi-lumped resonators placed into a metal case. Each resonator consists of a tubular capacitor connected in series between two tubular conductors. The measured frequency response of the fabricated filter is presented.* © 2012 Wiley Periodicals, Inc. Microwave Opt Technol Lett 54:1117–1118, 2012; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.26751

Key words: *bandpass filter; miniature filter; coaxial resonator; quasi-lumped resonator; ultra wide stopband*

1. INTRODUCTION

High selective narrowband bandpass filters are strongly required in modern wireless communication. To enhance the overall system performance, they must meet to such requirements as small size and wide stopband with high rejection level. For classical microwave filters based on half-wavelength and quarter-wavelength resonators, the upper boundary of the stopband is equal approximately to $2f_0$ and $3f_0$, respectively, where f_0 is the center frequency of the filter. To improve the performance of the rejection band, a number of approaches have been suggested. The stepped impedance resonators [1–3] and slow-wave resonators [4–7] have been found advantageous in designing microstrip bandpass filters with good stopband performance. Defected ground structures and slotted ground structures allow realizing wide stopband in planar bandpass filters as well [8, 9]. Combined and capacitively loaded interdigital filters [10] as well as stepped-impedance coaxial resonator filters [11–13] are also used to design device with wide rejection band.

Although good filters have the stopband that extends up to $10f_0$ at the rejection level of -30 dB, narrowband filters with much more high stopband performance are required in modern communication systems. In this article, we propose a compact two-resonator narrowband bandpass filter having the stopband that extends up to $40f_0$ at rejection level of -52 dB.

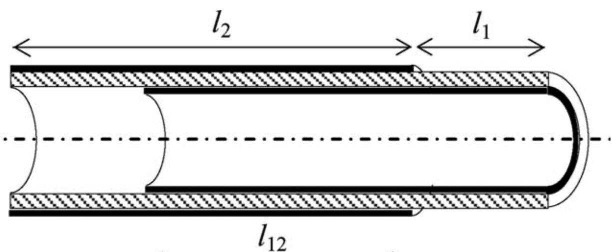

Figure 1 A longitudinal section of the quasi-lumped coaxial resonator without the metal case

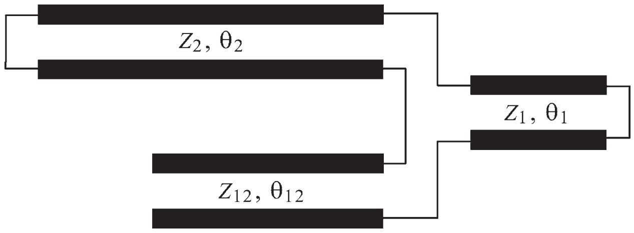

Figure 2 An equivalent circuit of the quasi-lumped coaxial resonator

2. A QUASI-LUMPED COAXIAL RESONATOR

Two quasi-lumped coaxial resonators are used in the bandpass filter. The structure of the resonator is shown in Figure 1. The resonator consists of two thin-film conductors partially covering inner and outer surfaces of a ceramic tube. The conductors overlap in a middle part of the tube forming a tubular capacitor. Two opposite ends of the conductors are connected to upper and lower walls of a metal enclosure of the filter.

The ceramic tube has inner radius of 1.6 mm, outer radius of 2.0 mm, and length of 15 mm. Ceramics of the tube have the dielectric constant of 33. The electric field of the fundamental oscillation mode is accumulated mainly in ceramics between two tubular conductors while magnetic field is accumulated mainly around the ceramic tube. Therefore, inductive coupling between two spaced parallel resonators inside the filter enclosure is to dominate over capacitive coupling.

An equivalent circuit of the coaxial resonator is shown in Figure 2. It has three coaxial transmission line sections that are connected in series. Kirchhoff's nodal rules give the following equation for the resonant frequencies of the coaxial resonator

$$Z_2 \tan \theta_2 + Z_1 \tan \theta_1 - Z_{12} \cot \theta_{12} = 0$$

Here Z_1, Z_2, and Z_{12} are transmission line impedances, and θ_1, θ_2, and θ_{12} are electrical lengths of the sections.

When wall thickness of the ceramic tube is rather thin in comparison with its radius, the impedance Z_{12} is extremely low. In this case, it follows from (1) that frequency of the fundamental oscillation mode is multiple times lower than frequency of the lowest higher-order mode and total length $l_1 + l_2$ of the resonator is multiple times shorter than the quarter wavelength in ceramics. Thus, the coaxial resonator is quasi-lumped. That is a feasibility condition for wide stopband.

It should be noted that making thinner the wall thickness of the ceramic tube not only lowers the fundamental mode

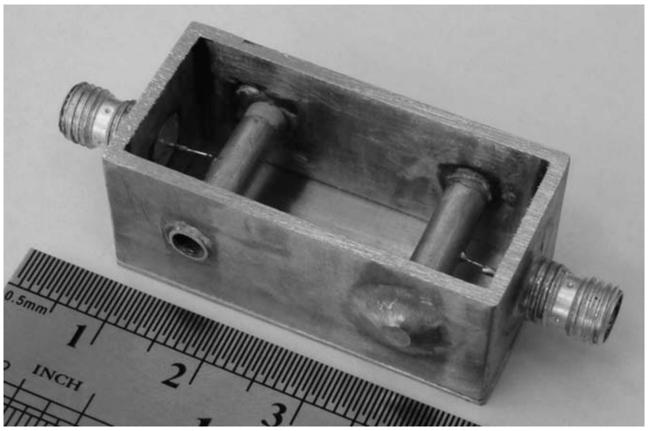

Figure 3 The photograph of the fabricated coaxial filter without the cover

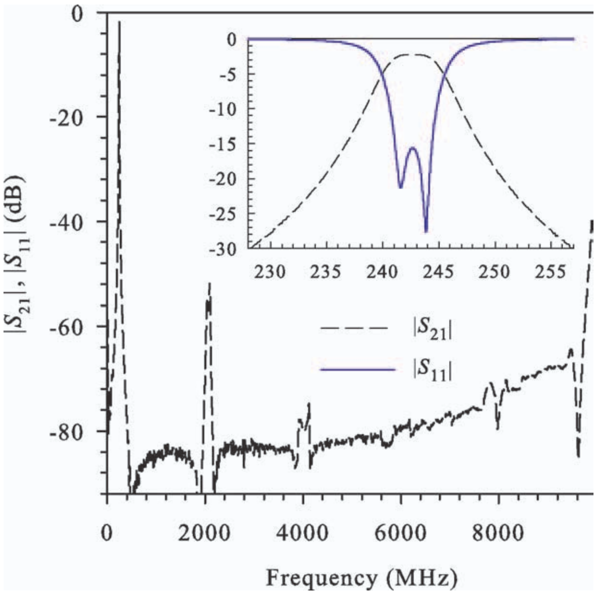

Figure 4 The measured frequency response of the fabricated coaxial filter. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

frequency but also heightens Q-factor of the resonator in a limited degree. This assertion also follows from (1) if all the values in the equation are considered as complex values.

3. A TWO-RESONATOR BANDPASS FILTER

The photograph of the designed and produced bandpass filter is shown in Figure 3. The filter consists of two interdigitally-coupled coaxial resonators placed into a metal enclosure. Outer tubular conductors of the resonators are tapped to the input and output connectors. The metal enclosure has internal dimensions of 35 mm × 15 mm × 15 mm. Distance between axes of the resonators amounts to 21 mm.

The measured frequency response of the fabricated coaxial filter is presented in Figure 4. The filter has a passband with the center frequency f_0 of 243 MHz, the minimum return loss of 15.7 dB, and the minimum insertion loss of 2.2 dB. Fractional 3-dB bandwidth amounts to 2.3%.

The first spurious peak arising at the frequency of $8.6f_0$ is suppressed down to -52 dB. The stopband at this rejection level extends up to $40f_0$. The stopband rejection outside the first spurious peak varies from -85 to -65 dB.

Strong suppression of the first and other spurious peaks is caused by the magnetic field localization close to the resonators for higher-order modes. As for spurious response higher than $40f_0$, it is generated by metal-case modes rather than resonator modes. Such high frequencies of metal-case modes are achieved because the small size of the resonators allows using the small size of the metal case.

4. CONCLUSIONS

A miniature bandpass filter having two interdigitally-coupled quasi-lumped coaxial resonators is proposed. Because of the short length of the resonators that amounts to $0.012\lambda_0$, the stopband of the filter extends up to $40f_0$ at the rejection level of -52 dB. The filter passband has the center frequency f_0 of 243 MHz and 3-dB fractional bandwidth of 2.3%. The metal enclosure of the filter has internal dimensions of $0.028\lambda_0 \times 0.012\lambda_0 \times 0.012\lambda_0$. The minimum insertion loss amounts 2.2 dB. Thus, the proposed filter differs in high performance in the stopband and small overall dimensions.

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V-BAND HIGH-ISOLATION CMOS T/R SWITCH FABRICATED USING 90-nm CMOS TECHNOLOGY

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