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Research Article

Wideband bandpass filter with sharp rejection using L-shaped stubs

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Abstract

Keywords:

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Bandpass filter,
L-shaped resonator,
Sharpness.

In this article a novel microstrip wideband bandpass filter is designed using L-shaped resonator. The proposed resonator has been studied using a circuit model and the electromagnetic (EM) and circuit simulations are performed and their agreement verifies the validity of the circuit model. Designed filter has a sharp rejection and good passband performance. The stopband attenuation level of the proposed filter is more than 40 db at the left side and this parameter is 20 db at the right one. The proposed filter has a central frequency of 6.81 GHz and its passband has a fractional bandwidth of 0.2. In this filter, the harmonics are suppressed in the range of DC to 5.78 GHz and 7.81 GHZ to 14 GHz. The designed filter is fabricated on RO4003 with 20 mil thickness and dielectric constant of 3.38.

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1. Introduction

Microstrip filters are in high demand in modern communication systems [1-4] and several methods have been proposed to design wideband band pass filters as an important part of microstrip filters A microstrip ultra wideband (UWB) bandpass filter (BPF) using the multiple-mode resonator is presented by Li and Zhu [5]. The multiple-mode resonator is formed by connecting three open-ended stubs with a stepped-impedance resonator. Adjusting the lengths of open stubs, results in the formulation of a novel UWB BPF with compact-size and widened upper-stopband. A wideband BPF using transversal resonator and interdigital coupled lines is proposed by Sun et al. [6]. In this work, a wide passband is first performed using transversal resonator and by driving this resonator with two asymmetrical interdigital coupled lines at two sides, the passband/stopband performance of the filter is improved. A compact UWB BPF with narrow notched band in the passband is presented by

Shaman and Hong [7] for use in wireless communication applications. This filter consists of five short-circuited stubs separated by connecting lines. The bandwidth of the notched band can be controlled by tuning the stubs width or the width of the gaps or both. A novel wideband BPF structure with input-output cross-coupling is investigated by shaman and hong [8]. This filter is consisted of a transmission line with short-circuited stubs. Cross-coupling between the input and output feed lines has improved the selectivity and group delay of the filter. A compact BPF with wide stopband is presented for the ultra-wideband communication systems by Monda and Mandal [9]. This filter is composed of a slot-line resonator with parallel feed lines. The stoband of this filter is expanded to 20 GHz with more than 20.9 dB rejection level. Filter occupying area is 0.26 lambdag times 0.28g, lambdag being the microstrip line guided wavelength at 6.85 GHz. Construction of a composite right/left-handed (CRLH) transmission line (TL) using microstrip coupled lines is presented by Mondal et al. [10]. In this filter for getting high coupling in comparison to conventional edge coupled microstrip line, the floating slot in the ground plane is used. This mentioned filter having bandwidth of 56.7% and selectivity of the 40 dB/GHz. Chen et al. [11] have presented a parallel coupled-line microstrip filter and fabricate it on PCB. This filter has presented almost very good characteristics including the simulated bandwidth of 67%, the measured bandwidth of 64%, lower insertion loss of 1.27 dB, and flat response in the pass-band. Makki and Rahmani [12] have presented a compact bandpass filter with a tuneable resonance frequency. This filter is designed using the stepped impedance sections and 20 dB rejection is obtained from 1.3 f_o up to 2.78 f_o in filter response. Li et al. [13] present two bandpass filters with wide stopband using multiple different resonators. In order to eliminate the second harmonic, the half- and quarter-wavelength resonators are utilized. The proposed filter could obtain 30 dB rejection level in the stopband from $1.2f_0$ to $3.8f_0$. Compact microstrip bandpass filters are proposed by Deng et al. [14]. These filters are based on the folded quarter-wavelength ($\lambda/4$) resonators, which are coupled through the shunt inductors connected to the ground.

In this paper a planar bandpass filter using L-shaped resonator is proposed. Good stopband attenuation level, low insertion loss in passband, sharp rejection and simple design process are advantages of this structure.

2. Design and study of the proposed filter

The layout, circuit model and EM/circuit simulation results of the proposed resonator are shown in the Figure 1. The proposed resonator is composed of two coupled lines that is coupled through a middle stub as shown in figure 1a. The circuit model of this resonator is presented to describe the behaviour of it. As it is depicted in figure 1b, in this circuit model, L1 and L2 are the inductances of the lateral and central lines respectively, Cg represents the coupling between transition lines and Ls and Cs is the inductance and body capacitance of the middle stub. The values of these LC parameters are calculated using equations (1-4). These parameters are as follows:

L1= 2 nH, L1= 2.6 nH, Cg= 0.14 pF, Ls= 1.15 nH and Cs= 0.22 pF.

$$C=[8.85\ (10)^{-12}\{[\frac{\varepsilon r\ w}{h}]^{1.08}+[2\pi(\frac{\varepsilon r+1}{2})(\frac{1}{\ln(\frac{8h}{w}+1)}-\frac{w}{8h})]^{1.08}\}^{0.926}]\ l \qquad (1)$$

$$L=\frac{l\ z_c}{v_p}\ ,\qquad v_p=\frac{c}{\sqrt{\varepsilon_{re}}} \qquad (2)$$

For w/h ≤ 1

$$\varepsilon_{re}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\{[1+12\frac{h}{w}]^{-0.5}+0.04[1-\frac{w}{h}]^2\}\ ,\qquad z_c=\frac{\eta}{2\pi\sqrt{\varepsilon_{re}}}\ln[8\frac{h}{w}+0.25\frac{w}{h}] \qquad (3)$$

For w/h ≥ 1

$$z_c=\frac{\eta}{\sqrt{\varepsilon_{re}}}\{\frac{w}{h}+1.393+0.677\ln[\frac{w}{h}+1.444]\}^{-1}\ ,\qquad \varepsilon_{re}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}[1+12\frac{h}{w}]^{-0.5} \qquad (4)$$

Where, C and L are capacitance and inductance of the resonator parts respectively, Zc is the characteristics impedance, V_p represents the phase velocity, w, l and h are line widths, line lengths and substrate thickness respectively, εre is the effective permittivity, η is a constant equal to 120π Ω and c represents the light speed.

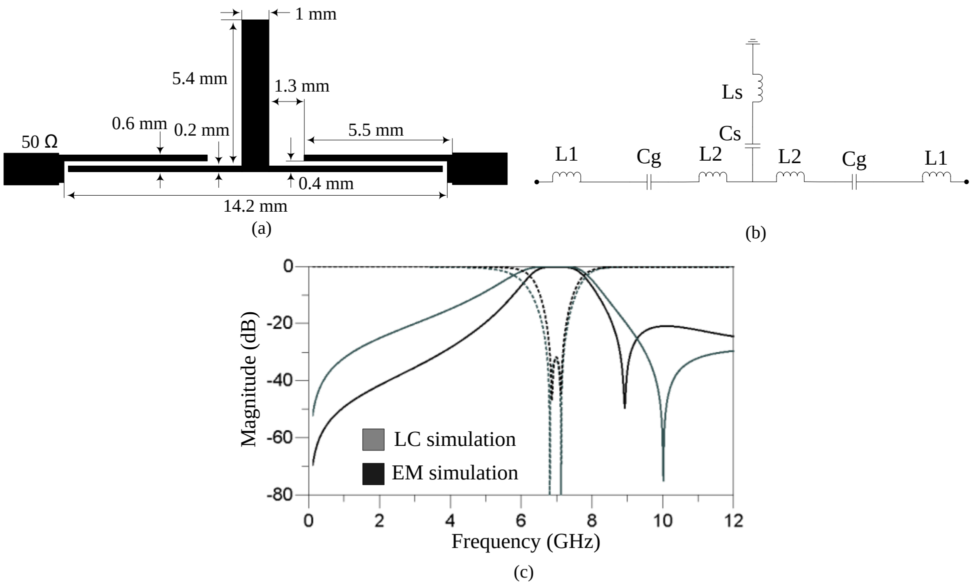

Fig.1: (a) Layout of the proposed resonator. (b) Circuit model of the proposed resonator. (c) LC/EM simulation results of the resonator.

To better understanding abut resonator structure, the surface current density distribution of the resonator at 7 GHz and 8.9 GHz (as the central frequency and the frequency of the near band transition zero) are depicted in Figure 2a and Figure 2b.

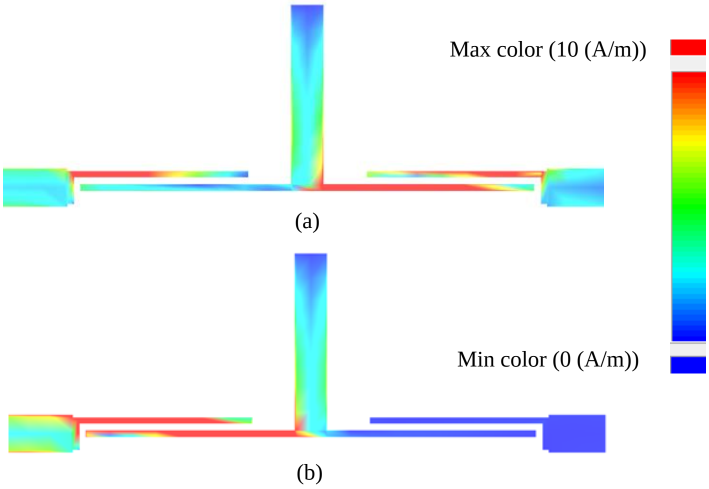

Fig.2: (a) the surface current density distribution of the resonator at 7 GHz. (b) the surface current density distribution of the resonator at 8.9 GHz

At the central frequency, the surface current density distribution of the resonator in coupled lines is higher than the other parts and this parameter at the frequency of the near band transition zero is increased in left coupled lines.

As it is shown in Figure 1c the transition bands of the resonator response are not sharp but the passband performance is good. To improve the transition bands, two resonators are cascaded and the final structure is created. The layout and simulation results of the proposed filter are shown in Figure 3.

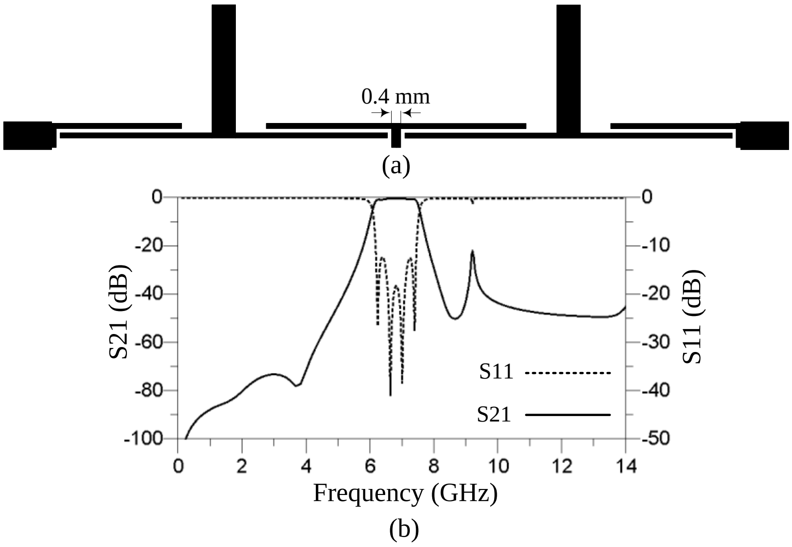

Fig.3: (a) the layout of the proposed filter. (b) the simulation results of the proposed filter

As it is shown in figure 3a all of the filter dimensions are the same of the resonator.

3. Results and discussion

The proposed wide band bandpass filter is fabricated on the RO4003 substrate with a dielectric constant of 3.38, a thickness of 0.508 mm and loss tangent of 0.0021. The size of the fabricated filter is 33.2×6.07 mm.

The simulated results of the filter have 3 dB Fractional Bandwidth (FBW) of 20% at 6.81 GHz; the maximum insertion loss within the whole wide passband is 0.71 dB and the minimum return loss is around 12.5 dB. There is no undesired harmonic on the left/right sides of the wide passband. On the left/right sides of the passband, the 20 dB rejection band is extended from DC to 5.78 GHz and 7.81 GHZ to 14 GHz respectively. The lower transition band from 5.78 to 6.12 and the upper transition band from 7.5 to 7.81 GHz with -3 and -20 dB are 0.34 and 0.31GHz respectively, showing that the filter has excellent sharpness performance.

4. Conclusions

A wideband bandpass filter with good selectivity, compact size and deep rejected stopband is designed. To study the structure of the proposed L-shaped resonator, its LC equivalent circuit was extracted and investigated in detail. The simulation results show that the proposed filter has a good passband performance and sharp roll-off. The mentioned features and the compact size make the designed filter suitable for a variety of modern communication systems. The proposed filter has a central frequency of 6.81 GHz and its passband has a fractional bandwidth of 0.2. In this filter, the harmonics are suppressed in the range of DC to 5.78 GHz and 7.81 GHZ to 14 GHz.

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