ELectronics EXpress

IEICE Electronics Express, Vol.8, No.13, 1028–1033

Compact lowpass filter with ultra-wide stopband using novel spiral compact microstrip resonant cell

Mohsen Hayati[a] **and Akram Sheikhi**

Electrical Engineering Department, Islamic Azad University, Kermanshah Branch, Kermanshah, Iran

a) *mohsen_hayati@yahoo.com*

Abstract: In this paper a novel spiral compact microstrip resonant cell (NSCMRC) to design a low pass filter with wide stopband is presented. The slow-wave effect and scattering and radiation parameters are depicted. The designed lowpass filter is implemented by cascading three cells with different dimensions that shows the advantages of low insertion loss less than 0.03 dB and wide stopband from 4 GHZ up to 50 GHZ with suppression level better than −13.4 dB and compact size. Finally, the proposed lowpass filter is fabricated and a good agreement between simulated and the measured results are demonstrated.

Keywords: microstrip lowpass filter, spiral compact microstrip resonant cell, wide stopband.

Classification: Microwave and millimeter wave devices, circuits, and systems

References

[1] J. Z. Gu, W. Y. Yin, R. Qian, C. Wang, and X. W. Sun "A Wideband EBG structure with 1D compact microstrip resonant cell," *Microw. Opt. Technol. Lett.*, vol. 45, no. 5, pp. 386–387, June 2005.

[2] J. Gu and X. Sun, "Compact lowpass filter using spiral compact microstrip resonant cells," *Electron. Lett.*, vol. 41, no. 19, pp. 1065–1066, Oct. 2005.

[3] K. Deng, Q. Xue, and W. Che, "Improved compact microstrip resonance cell lowpass filter with wide stopband characteristics," *Electron. Lett.*, vol. 43, no. 8, pp. 463–464, April 2007.

[4] F. Zhang, C. Gu, L. Shi, C. Li, J. Gu, and X. Sun, "In-line beeline CMRC and applications to compact microstrip low-pass filter," *Microw. Opt. Technol. Lett.*, vol. 48, no. 6, pp. 1125–1127, June 2006.

[5] F. Zhang, J. Z. Gu, C. Y. Gu, L. N. Shi, C. F. Li, and X. W. Sun, "Lowpass filter with in-line beeline CMRC," *Microw. Opt. Technol. Lett.*, vol. 42, no. 8, pp. 472–474, April 2006.

[6] M. Hayati and A. Lotfi, "Elliptic-function lowpass filter with sharp cutoff frequency using slit-loaded tapered compact microstrip resonator cell," *Electron. Lett.*, vol. 46, no. 2, pp. 143–144, Jan. 2010.

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011

[7] F. Zhang and C. F. Li, "UWB lowpas filter with novel comb CMRC," *Microw. Opt. Technol. Lett.*, vol. 50, no. 8, pp. 2077–2079, Aug. 2008.

1 Introduction

Microstrip low pass filters with high performance and compact size are key blocks in microwave communication systems to suppress unwanted harmonics and spurious signals. Therefore, a wide stop band, low insertion loss and compact size are important factors in designing the low pass filters. Recently planar resonators are used because of their compact size and easy fabrication with the other microwave circuits. In the recent years, several researche on Compact Microstrip Resonance Cell have been done to design LPF with compact size.

The design of novel 1-D compact microstrip resonant cells (CMRC) in [1], shows the characteristics of the wide stopband and compact size. In [2] and [3], LPFs employing SCMRCs and improved CMRCs is proposed. In [4] and [5], lowpass filter with in-line beelines CMRC are designed. Elliptic-function lowpass filter using slit-loaded tapered compact microstrip resonator cell proposed in [6] has sharp cutoff frequency. In [7] UWB low-pass filter with novel comb CMRC with compact size and wide stop-band is proposed.

In designing LPFs, compact size, low insertion loss in the passband and wide stopband are necessary. To reach these requirements, in this paper we have proposed a novel spiral CMRC (NSCMRC), which shows the slow-wave and bandstop characteristics. By using this resonator, a LPF is designed, fabricated and measured.

2 Design of the lowpass filter

To reach slow wave effect for circuit size reduction, we have designed NSCMRC that shows in Fig. 1 (a). As can be seen from Fig. 1 (a) this NSCMRC consists of four horizontal beeline and eight folded lines, which are loaded by triangular patches. The beeline enhances the inductance, while the coupling gaps between the lines increase the capacitance of the transmission line. The increase in inductance and capacitance equivalent turns the design to slow wave transmission line. The designed resonator is based on the substrate with the dielectric constant 2.2, thickness 15 mil and loss tangent equal to 0.0009. The NSCMRC parameters are: L0 = 1.95 mm, L1 = 4.7 mm, L2 = 2.85 mm, W0 = 0.15 mm, W1 = 0.125 mm, W2 = 0.325 mm, W3 = 0.15 mm, S0 = 0.125 mm, S1 = 0.15 mm, S2 = 0.125 mm, S3 = 0.3 mm, S4 = 0.125 mm. Assuming the structure is loss-less, its phase velocity can be given by:

$$v_p = \frac{1}{\sqrt{lc}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-0.5} \tag{2}$$

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011

$$SWF = \frac{\lambda_0 \Delta\theta}{360L} + \sqrt{\varepsilon_{eff}} \qquad (3)$$

where L is a physical length of microstrip line, λ_0 is the guided wavelength at cutoff frequency; $\triangle\theta$ is the phase difference between the conventional microstrip and the proposed resonator and ε_{eff} is the effective microstrip permittivity. Fig. 1 (b) shows the slow-wave factor of the proposed resonator in term of frequency.

It can be seen from the result that the uniform 50 ohm microstrip line has SWF equal to 1.4 in the passband region, where the SWF of the proposed resonators increases and reaches 6.6 in the region close to 3-dB cutoff frequency. So we have 285.7% increment in SWF up to 5 GHZ and 470% incre-

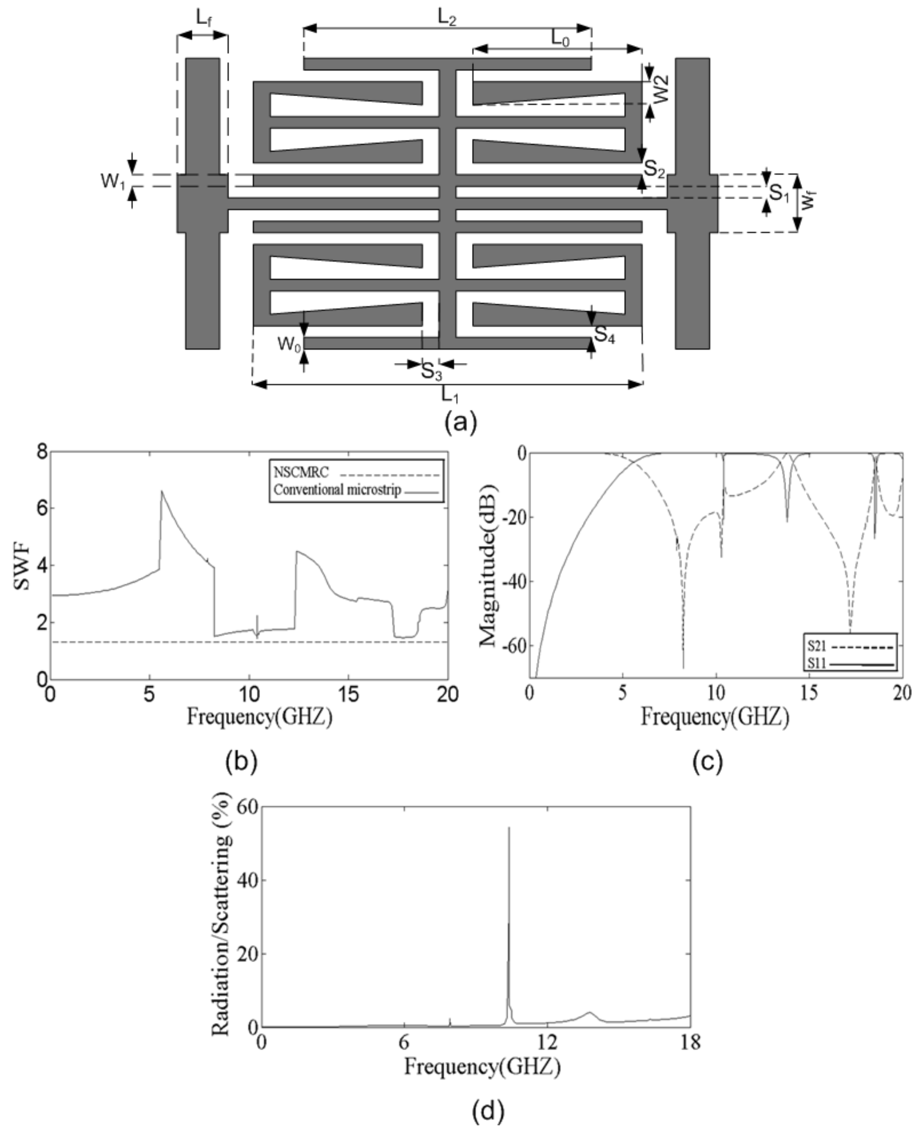

Fig. 1. (a) Schematic diagram of proposed Novel Spiral Compact Microstrip Resonance Cell. (b) Calculated SWFs of the NSCMRC and the conventional microstrip line. (c) Simulated S-parameters for the proposed resonator. (d) Simulated radiation and scattering levels for the NSCMRC.

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011

IEICE Electronics Express, Vol.8, No.13, 1028–1033

ment in SWF around 6 GHZ in comparison with the conventional microstrip line. Fig. 1 (c) shows the simulated results of this resonator. Transmission parameters S21 in passband region shows the insertion loss equal to 0 dB.

The radiation and scattering parameters is defined with $1-|S11|^2-|S21|^2$. As shown in Fig. 1 (d) the radiation and scattering are maintained at low levels until the frequency is below 10.4 GHz. In Fig. 2 (a) and Fig. 2 (b), the S21 parameter simulation as a function of L0 and W2 is shown. By decrement of L0 and W2 the transmission zero closes to upper frequency, due to decrement of equivalent inductance and capacitance, respectively. So we can control the location of transmission zero at 8.24 GHZ with changing L0 and W2.

To reject the unwanted frequency and reach the wide stopband, we use three cells with different dimensions. By connecting three cells with different dimensions in series, the periodic structure exhibits the stopband characteristics because of the mutual suppression of the spurious passband. The schematic of the designed filter is shown in Fig. 2 (c). In order to reach a low radiation loss in the stopband region, we use open stubs, located on 50 ohm microstrip line at input and output ports, which are shown in Fig. 2 (c).

The proposed lowpass filter has been simulated and fabricated on a substrate with a relative dielectric constant = 2.2, thickness h = 15 mil, and loss tangent = 0.0009. In the first cell: L1 = 5.17 mm, L2 = 5.17 mm, W0 = 0.15 mm, W1 = 0.14 mm, W2 = 0.3 mm, W3 = 0.15 mm, S1 = 0.15 mm, S2 = 0.125 mm, S3 = 0.125 mm, S4 = 0.1 mm and in the second cell: L2 = 5.36 mm, W0 = 0.15 mm, W1 = 0.125 mm, W2 = 0.45 mm, S1 = 0.15 mm, S2 = 0.125 mm, S3 = 0.125 mm, S4 = 0.1 mm, S5 = 0.22 mm. Two open microstrip stubs with Wt = 0.45 mm and Lt = 3.65 mm at both sides of the LPF are in order to suppress the harmonics at stop band. In order to match the impedance at input and output ports to 50 ohm, we have used two microstrip open stubs at input and output ports with Wf = 1.15 mm and Lf = 0.83 mm.

3 Measured and simulated results

The photograph of the fabricated LPF is shown in Fig. 3 (a). Fig. 3 (b) shows the comparison of the simulated and the measured results. We have simulated the proposed lowpass filter with an EM-simulator ADS based on the method of moment. The S-parameter is measured by HP8757A network analyzer. The results show that the proposed filter has 3 dB cut-off frequency at 3.55 GHZ; the insertion loss from DC to 2 GHZ is 0.03 dB. The return loss is better than −21 dB, so we have good power handling in designed filter. The return loss in the stopband region is close to 0 dB, so we have low radiation loss.

The filter has no ripples because of one attention pole at 2 GHZ with attenuation level equal to −43.98 dB. With two transmission zeros at 5.27 GHZ and 6.09 GHZ with attenuation level equal to −81 dB and −71 dB respectively, we have sharp skirt performance. In addition the flat groupdelay in

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011

IEICE Electronics Express, Vol.8, No.13, 1028–1033

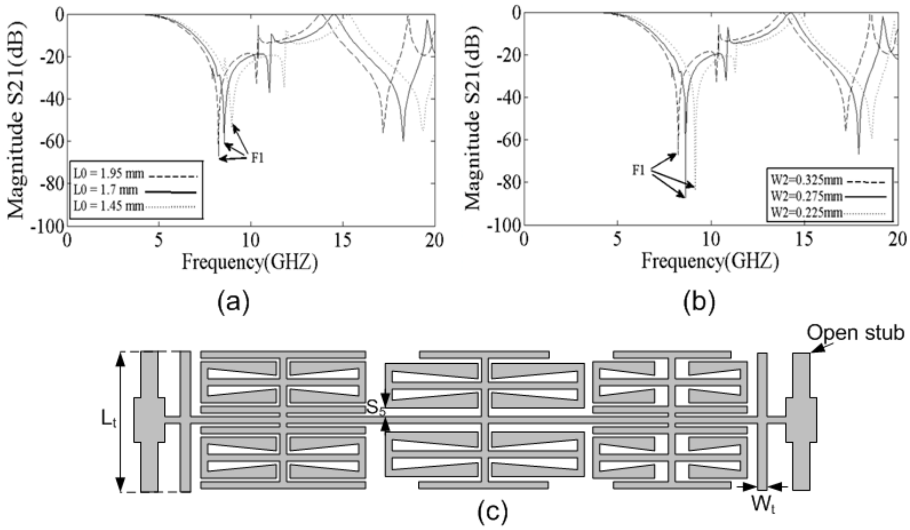

Fig. 2. (a) S21 parameter simulation of the proposed resonator as a function of L0. (b) S21 parameter simulation of the proposed resonator as a function of W2. (c) Schematic diagram of the proposed LPF

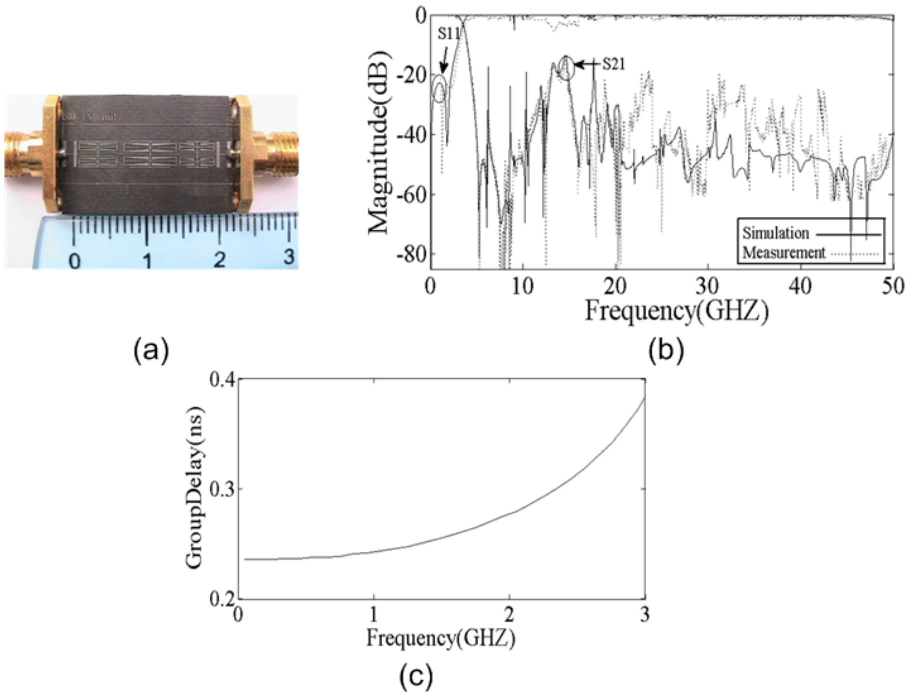

Fig. 3. (a) Photograph of the fabricated LPF. (b) Magnitude responses of the full-wave EM simulation and experiment. (c) The group delay of the proposed lowpass filter

Fig. 3 (c) is achieved in the passband region with the maximum variation of 0.4 ns. Our work in comparison to conventional SCMRC in [2] has 77% reduction in size, 42% increase in pass bandwidth, 86% increase in the stop bandwidth. In this filter, in spite of using three cells we have low insertion loss close to 0 dB. Excluding 50 ohm microstrip line, the circuit size is

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011

$22.5\,\mathrm{mm} \times 3.7\,\mathrm{mm}$.

4 Conclusion

The ultra wide stopband lowpass filter has been developed with the novel Spiral Compact Microstrip Resonance Cell (NSCMRC). This prototype filter has been simulated, fabricated and measured. The proposed filter shows good characteristics in the passband and the stopband; the insertion loss is less than 0.03 dB and the return loss is better than −21 dB; and the stop bandwidth is 174%. The compact size, the low insertion loss and the wide stopband would make the proposed filter used in modern wireless communication systems.

DOI: 10.1587/elex.8.1028
Received May 06, 2011
Accepted June 06, 2011
Published July 10, 2011