Int. J. Electron. Commun. (AEÜ) 94 (2018) 79–83

Contents lists available at ScienceDirect

Int. J. Electron. Commun. (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Regular paper

Compact, high selectivity and wideband bandpass filter with multiple transmission zeros

Kanaparthi V. Phani Kumar[a,*], S.S. Karthikeyan[b]

[a] Department of Electronics and Communication Engineering, SRM Institute of Science and Technology, Kattankulathur 603203, Tamil Nadu, India
[b] Department of Electronics and Communication Engineering, National Institute of Technology Tiruchirappalli, Tiruchirappalli 620015, Tamil Nadu, India

ARTICLE INFO

Keywords:
Bandpass filter
Wideband
High selectivity
Coupled line
Stepped impedance modified Π-type

ABSTRACT

This paper presents the design of a compact, high selectivity and wideband bandpass filter based on signal interference technique. The proposed filter consists of open coupled line and stepped impedance modified Π-type (SMΠ) transmission line with short circuited stubs in transmission path 1 and path 2, respectively. Due to the superposition of signals of the two transmission paths, a fourth-order wideband bandpass filter with six transmission zeros can be obtained from 0 to $2f_0$ (f_0 is the operating frequency). A bandpass filter prototype centring at 0.9 GHz, with 3 dB fractional bandwidth of 50% is designed, fabricated and tested. Good agreement is found between the simulated and experimental results.

1. Introduction

Bandpass filters (BPFs) with properties of sharp selectivity, wide passband/stopband, low insertion loss in the passband and high rejection in the stopband are very much essential for the design of transmitters and receivers used in present day modern microwave communication system [1]. In order to meet these requirements, several techniques have been reported [2–13]. In spite of having narrow/wide passband, good insertion loss and high selectivity due to multiple transmission zeros in the stopband, most of the reported BPFs are occupying larger circuit area. Techniques like branch line resonator [2], open/shorted dual behavior resonator (DBR) [3], shorted coupled line and open/shorted stubs [4] and rectangular dual spiral resonator [5] are used to realize BPFs with multiple transmission zeros and their 3 dB fractional bandwidths (FBWs) are ranging between 5.9% and 7.69% only. A compact dual-mode coupled line resonator with wider external quality factor is proposed in [6] and the resonator is utilized to design a high selectivity BPF with two transmission zeros. In [7], a compact and high performance planar BPF based on the substrate integrated waveguide and compact microstrip resonant cell technique is reported. Its overall circuit size and 3 dB FBW are $0.24\lambda_g \times 1.24\lambda_g$ (λ_g being the guided wavelength) and 30.6%, respectively. Transversal signal interference technique (SIT) is a popular and widely used method to design high performance filters. Wideband BPFs based on SIT with multiple transmission zeros and bandwidth greater than 35% are realized using open/shorted coupled lines and T-shaped structure [8,9,11], modified branch line structure [13], and all these prototype filters are occupying large circuit area. In [10], a parallel coupled microstripline and an open-ended stub are utilized to design a sharp rejection microstrip BPF. The reported BPF (Filter-A) is having six transmission zeros and the overall circuit size is $0.51\lambda_g \times 0.20\lambda_g$. The conventional two-stage parallel coupled line structure is modified in [12] and it is utilized to design a high performance wideband BPF.

This paper aims at designing sharp selectivity, wideband, good out-of-band rejection bandpass filter with compact topology. The filter design is based on SIT, in which, path1 and path 2 consists of an open coupled line and a stepped impedance modified Π-type transmission line with shorted stubs (SMΠS), respectively. The SMΠ transmission line with open stubs is proposed in [14] as an equivalent to a 90° transmission line and designed a compact branch line hybrid. The SMΠ transmission line is modified with shorted stubs and used in this work for designing a compact wideband BPF. The bandwidth of the filter can be easily adjusted by changing the coupling coefficient of the open coupled line and the characteristic impedance of the SMΠS. A BPF with six transmission zeros and 3 dB FBW of 50% is designed and fabricated on RT duroid 5870 substrate having $\epsilon_r = 2.33$, loss tangent = 0.0012 and thickness of 0.787 mm. R&S ZVL vector network analyzer is used for testing the fabricated prototype. The proposed filter is occupying a compact area of $0.26\lambda_g \times 0.26\lambda_g$. Detailed theoretical design, simulation and measured results are demonstrated and discussed.

2. Proposed filter analysis and design

The schematics of the open coupled line (even and odd mode

* Corresponding author.
E-mail addresses: phanikumar.k@ktr.srmuniv.ac.in, edm13d001@iiitdm.ac.in (K.V. Phani Kumar).

https://doi.org/10.1016/j.aeue.2018.06.047
Received 14 December 2017; Accepted 28 June 2018
1434-8411/

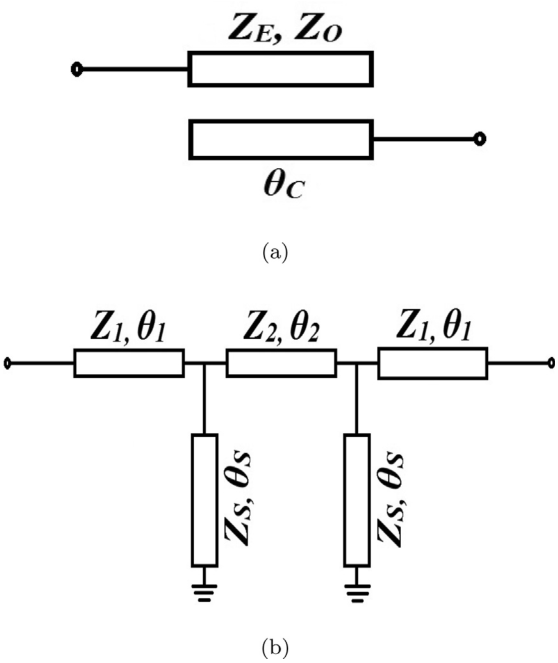

Fig. 1. Transmission line model of (a) open coupled line and (b) SMΠS line.

characteristic impedances Z_E, Z_O and electrical length θ_C) and SMΠS transmission line (with series and shunt characteristic impedances Z_1, Z_2, Z_S and electrical lengths θ_1, θ_2, θ_S) are shown in Fig. 1(a) and (b), respectively. The transmission line model and layout of the proposed wideband BPF with six transmission zeros after connecting coupled line in path 1 and SMΠS transmission line in path 2 are shown in Fig. 2(a) and (b), respectively.

The ABCD parameters of path 1 and path 2 are given as [1]:

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}_{Path1} = \begin{bmatrix} \frac{Z_E+Z_O}{Z_E-Z_O}\cos\theta_C & j\frac{(Z_E-Z_O)^2-(Z_E+Z_O)^2\cos^2\theta_C}{2(Z_E-Z_O)\sin\theta_C} \\ j\frac{2\sin\theta_C}{Z_E-Z_O} & \frac{Z_E+Z_O}{Z_E-Z_O}\cos\theta_C \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}_{Path2} = M_1 M_S M_2 M_S M_1 \quad (2)$$

where

$$M_1 = \begin{bmatrix} \cos\theta_1 & jZ_1\sin\theta_1 \\ \frac{j\sin\theta_1}{Z_1} & \cos\theta_1 \end{bmatrix} \quad (3)$$

$$M_2 = \begin{bmatrix} \cos\theta_2 & jZ_2\sin\theta_2 \\ \frac{j\sin\theta_2}{Z_2} & \cos\theta_2 \end{bmatrix} \quad (4)$$

$$M_S = \begin{bmatrix} 1 & 0 \\ \frac{-j\cot\theta_S}{Z_S} & 1 \end{bmatrix} \quad (5)$$

$$A_2 = D_2 = \sin 2\theta_1 \sin\theta_2\left(\frac{Z_1\cot\theta_2\cot\theta_S}{Z_S} - \frac{Z_1^2+Z_2^2}{2Z_1Z_2} + \frac{Z_1Z_2\cot^2\theta_S}{2Z_S^2}\right) + \cos 2\theta_1\cos\theta_2\left(1+\frac{Z_2\tan\theta_2\cot\theta_S}{Z_S}\right) \quad (6)$$

$$B_2 = jZ_1\sin 2\theta_1\left(\cos\theta_2 + \frac{Z_2\sin\theta_2\cot\theta_S}{Z_S}\right) + jZ_2\cos^2\theta_1\sin\theta_2 + jZ_1^2\sin^2\theta_1\left[\frac{2\cos\theta_2\cot\theta_S}{Z_S} - \sin\theta_2\left(\frac{1}{Z_2} - \frac{Z_2\cot^2\theta_S}{Z_S^2}\right)\right] \quad (7)$$

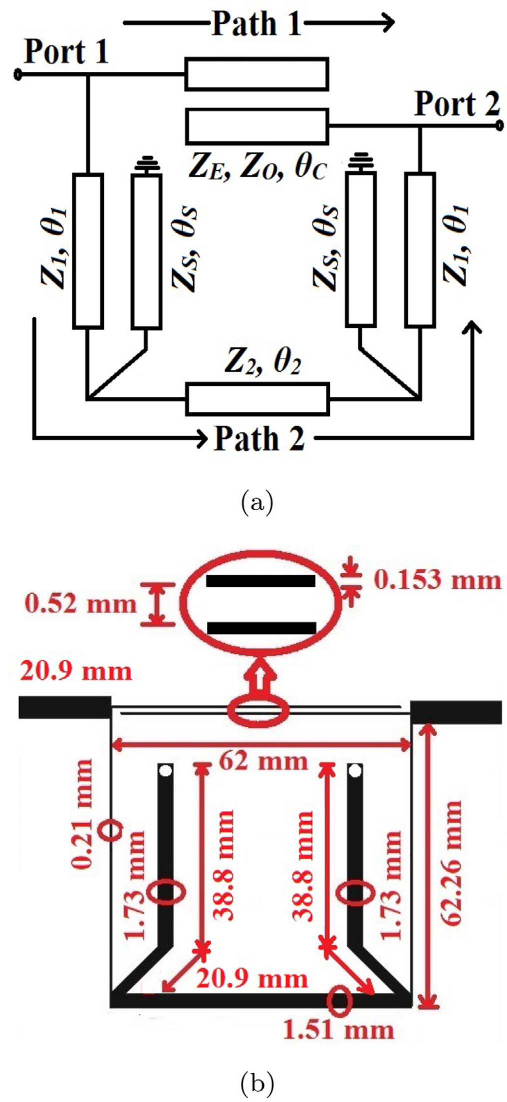

Fig. 2. Proposed wideband BPF with six transmission zeros (a) transmission line model and (b) layout.

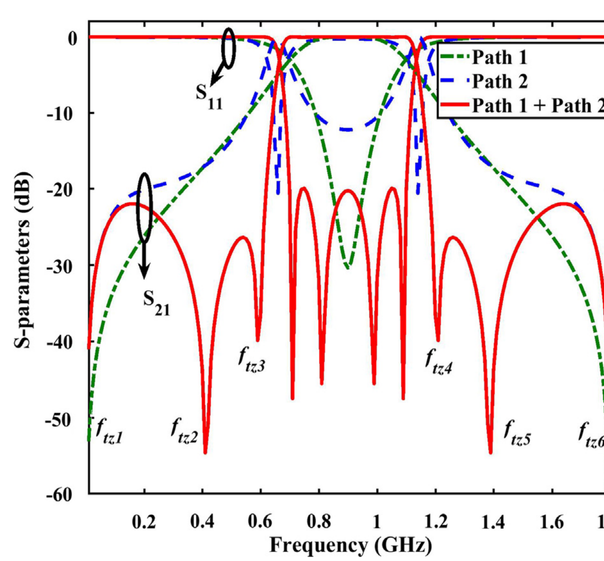

Fig. 3. Circuit simulated magnitude response of the proposed wideband BPF (Z_1 = 134.5 Ω, Z_2 = 45 Ω, Z_S = 40 Ω, Z_E = 250 Ω, Z_O = 153 Ω, $\theta_1 = \theta_2 = \theta_S = \theta_C = 90°$, f_0 = 0.9 GHz).