A Compact Wideband Bandpass Filter Based on Stepped Impedance Line Sections

Guo-Yun Wang, Chi-Feng Chen, *Member, IEEE*, and Jhong-Jhen Li
Department of Electrical Engineering, Tunghai University, Taichung, Taiwan 40704

***Abstract*--This paper presents a design of compact wideband bandpass filter (BPF). The BPF is based on the traditional highpass filter formed by three short-circuited stubs separated by uniform impedance lines. Since the uniform impedance line sections of the traditional filter are replaced by the stepped impedance lines, the size of the filter can be miniaturized. For a demonstration, a compact BPF with center frequency of 1.3 GHz and fractional bandwidth of 85% has been designed and implemented in microstrip technology. The size of the fabricated BPF is only about 0.45 λ_g by 0.8 λ_g. Moreover, the experimental results are in good agreement with the simulation predictions.**

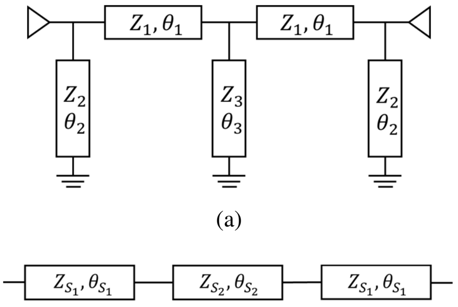
I. INTRODUCTION

In modern multi-service and multi-band communication systems. Bandpass filter (BPF) is an important and essential component in RF/microwave front ends of both receiver and transmitter. In general, BPFs are always require high compactness, low cost, and ease to realize. In recent years, several high-performance BPFs with wideband frequency response have been proposed [1]–[9]. In [1], [2], wideband BPFs with spurious response suppression are presented. In [3]–[9], wideband BPFs are designed based on different multi-mode resonators. Since these BPFs are realized by only one resonator, the circuit size can be significantly reduced. However, with the rapid growth of the modern communication systems, the size reduction is still an important topic in developing wideband BPFs.

In this paper, a compact-size wideband BPF has been proposed. For the purpose of the size reduction, the equivalent stepped impedance lines are employed to design the BPF. The detailed design procedure for the proposed wideband BPF is described as follows. The EM simulation and measurement are also obtained to verify the ideal.

II. CIRCUIT DESIGN

The filter design is based on the traditional highpass filter as shown in Fig. 1(a). As seen, the filter is formed by three short-circuited stubs separated by uniform impedance lines [10]. When the center frequency and fractional bandwidth are given as 1.3 GHz and 85%, respectively, the electrical lengths and characteristic impedances of these transmission lines can be obtained as θ_1 = 103.1°, θ_2 = 103.1°, θ_3 = 100.6°, Z_1 = 48.9 Ω, Z_2 = 49.1 Ω, and Z_3 = 48.3 Ω. In order to reduce the circuit size, the equivalent stepped impedance line section shown in Fig. 1(b) is used to replace the uniform impedance line section of the traditional filter. The *ABCD* matrix the uniform impedance line section can be written as



(b)

Fig. 1. (a) Circuit model of the traditional filter. (b) Stepped impedance line section.

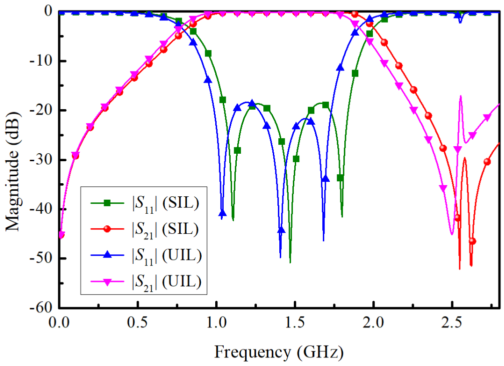


Fig. 2. Simulated frequency responses of the filter. (SIL: stepped impedance line; UIL: uniform impedance line)

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_1 = \begin{bmatrix} \cos\theta_1 & jZ_1\sin\theta_1 \\ \dfrac{j}{Z_1}\sin\theta_1 & \sin\theta_1 \end{bmatrix} \qquad (1)$$

While the *ABCD* matrix of the stepped impedance line section can be obtained as equation (2). By enforcing $\begin{bmatrix} A & B \\ C & D \end{bmatrix}_1 = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_2$, the required design parameters of the stepped

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_2 = \begin{bmatrix} \cos\theta_{S_2}(\cos\theta_{S_1}{}^2 - \sin\theta_{S_1}{}^2) - 2\dfrac{Z_{S_1}}{Z_{S_2}}\cos\theta_{S_1}\sin\theta_{S_1}\sin\theta_{S_2} & (\cos\theta_{S_1}{}^2 - \sin\theta_{S_1}{}^2)(jZ_{S_2}\sin\theta_{S_2}) + 2jZ_{S_1}\sin\theta_{S_1}\cos\theta_{S_1}\cos\theta_{S_2} \\ \cos\theta_{S_2}\left(-\dfrac{1}{Z_{S_2}{}^2}\cos\theta_{S_1}\sin\theta_{S_1}\right) + j\dfrac{1}{Z_{S_2}}\sin\theta_{S_2}\,(\cos\theta_{S_1}{}^2 - \sin\theta_{S_1}{}^2) & \cos\theta_5(\cos\theta_{S_1}{}^2 - \sin\theta_{S_1}{}^2) - 2\dfrac{Z_{S_1}}{Z_{S_2}}\cos\theta_{S_1}\sin\theta_{S_1}\sin\theta_{S_2} \end{bmatrix} \qquad (2)$$

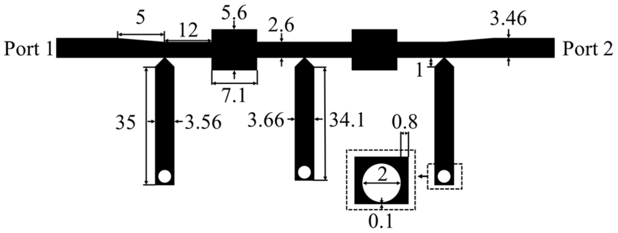


Fig. 3. Schematic layout of the proposed wideband BPF based on stepped impedance line. (unit: mm)

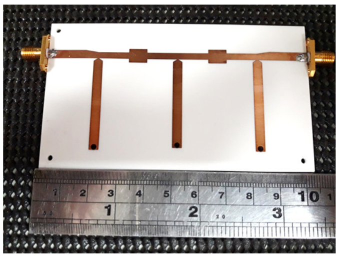


Fig. 4. Photograph of the proposed wideband BPF.

impedance line can then be calculated as $\theta_{S_1} = 34.9°$, $\theta_{S_2} = 21.3°$, $Z_{S_1} = 59.2\Omega$ and $Z_{S_2} = 36.3\Omega$. It can be found that the length of the stepped impedance line section is smaller than that of the traditional uniform impedance line and, therefore, the size reduction can be achieved. The performance comparison for the two cases is illustrated in Fig. 2. It reveals the proposed stepped impedance line section can perform as a traditional uniform impedance line over the desired passband.

For a demonstration, a microstrip wideband BPF was designed to be fabricated using copper metallization on a Rogers RO4003 substrate with a relative dielectric constant of 3.38, a thickness of 1.524 mm, and a loss tangent of 0.0027. The schematic layout of the wideband BPF is shown in Fig. 3. The size of the BPF is 57 mm by 100 mm, i.e. only approximately 0.45 λ_g by 0.8 λ_g, where λ_g is the guided wavelength on the substrate at the center frequency of the passband. It should be noted that since the uniform transmission line sections are replaced by the stepped impedance line sections, the size of the BPF can be miniaturized, which is about 13% size reduction in comparison with the conventional ones. The photograph of the fabricated wideband BPF is shown in Fig. 4.

III. SIMULATION AND MEASUREMENT

The measured and simulated results of the proposed wideband BPF are shown in Fig. 5. As can be seen, the measured results of the BPF exhibit an excellent agreement with simulation. The measured in-band return loss is better than 15 dB and the measured in-band insertion loss is about 0.5 dB. Note that the insertion loss is mainly attributed to the conductor loss.

IV. CONCLUSION

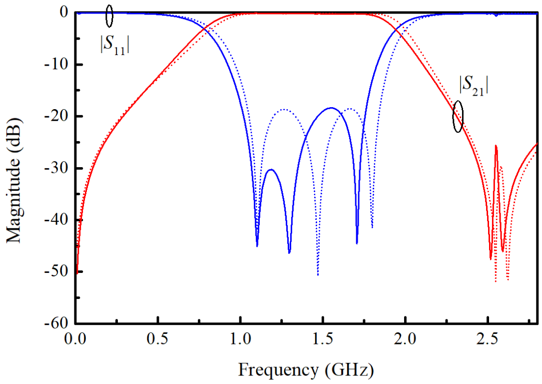


Fig. 5. EM simulated and measured results of the proposed wideband BPF. (solid lines: measurement; dashed lines: simulation)

In this paper a compact wideband BPF based on the stepped impedance line sections has been proposed. By replacing the uniform transmission line sections with stepped impedance line sections from the traditional filter, the filter size can be reduced. For a demonstration, a microstrip wideband BPF with a compact size of 0.45 λ_g by 0.8 λ_g was designed and implemented. Good agreement has been observed between the simulation and measurement. The proposed wideband BPF has the advantages of compact size, high performance, and ease to realize, making it a good candidate for many applications, such as wideband communication systems.

ACKNOWLEDGMENT

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