Harmonic Suppressed Short-Stub Bandpass Filter with T-type Inverter

Sun-Kuk Noh [1], Tae-Soon Yun[2]

[1]Dept. of Photoelectronics Information, Chosun College of Science & Technology, GwangJu, KOREA, E-mail: nsk7078@hanmail.net
[2]Dept. of Radio Mobile Communication Eng., Honam Univ.,
330 Eodeungno, Gwangsan-gu, Gwangju 506-714, Korea
TEL) +82-62-940-5571, FAX) +82-62-443-0106
E-mail: easteryun@gmail.com

Abstract. A simplified design method of harmonic suppressed short-stub bandpass filter (BPF) is proposed. The short-stub BPF is designed by equations of the tapped-line geometry and its second and third harmonics are suppressed by additional open-stubs of the T-type equivalent circuits for the quarter wavelength transmission line. Design parameters for the tapped-line geometry are obtained using the equivalent circuit of the J-inverter for the filter prototypes. The harmonic suppressed short-stub BPF with the center frequency of 2.4 GHz is implemented on Teflon substrate and compared with conventional short-stub BPF. Also, the second and third harmonics of the short-stub BPF are suppressed over 30 dB up to 10 GHz.

Keywords: bandpass filter (BPF), short-stub, harmonic, tapped-line, inverter.

1 Introduction

In the filter, a tapped feeding method has been applied to various filter types such as a combline filter, an interdigital filter, an edge coupled filter, and so on [1-6]. For the design of a filter using tapped-line, an open-wire-line equivalent circuit approach has been suggested [1-2], the tapped feeding method is realized such that the *J*-inverter of filters is replaced with tapped feed-line. Especially, in our previous work, tapped-line is realized on the open-stub and additional transmission-line which has negative electrical length [3].

Also, in order to obtain high selectivity of bandpass filters (BPFs), more resonators are used or the elliptic-function response is used such as open-loop resonators and ring resonators. The elliptic-function BPFs have transmission zeros and show high selectivity by using smaller number of the resonator [4]. As using tapped-line geometry, the transmission zero can be obtained by the open-stub and BPFs can be realized with high selectivity.

In this paper, a harmonics suppressed short-stub BPF is suggested and realized by inserting the T-type equivalent circuit for the $\lambda_g/4$ line as the inverter. This filter provides compact design, sharp skirt characteristic, and second and third harmonic suppressed characteristic. As illustrated in Fig. 1(c), the proposed short-stub BPF is formed by adding T-type equivalent circuit at the conventional $\lambda_g/4$ short-stub BPF.

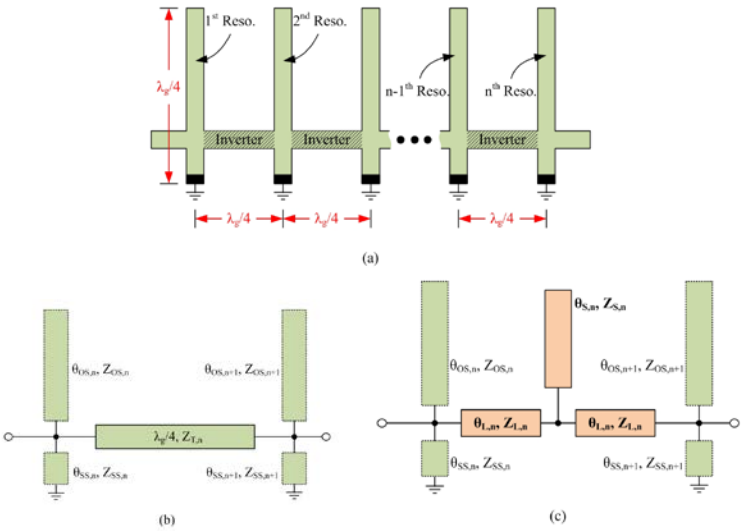

Fig. 1. Schematic of (a) the conventional narrow-band short-stub BPF using tapped-line geometry, (b) the quarter wavelength transmission line as the *n*'th inverter, and (c) the T-type inverter as alternating by the T-type equivalent circuit for the quarter wavelength transmission-line

2 Design of Harmonic Suppressed Short-Stub Bandpass Filter

In our previous work, for the tapped-line geometry, the *J*-inverter can be alternated as the open-stub, short-stub, and additional transmission-line. Also, their electrical lengths and impedances are demonstrated [3, 6]. Fig. 1(a) shows the conventional short-stub BPF using tapped-line geometry, in this prototype, each resonator is separated by the $\lambda_g/4$ connecting transmission line as the inverter. Fig. 1(b) and (c) are the quarter wavelength transmission line as the n'th inverter and the T-type inverter as alternating by the T-type equivalent circuit for the quarter wavelength transmission-line, respectively, where Z_{in} is the characteristic impedance and θ_{in} is the electrical length of the stub and transmission line (i = T, L, S, and n = 1, 2, 3). The T-type equivalent circuit of the quarter wavelength transmission line can be obtained by using the ABCD matrix. General equations for Z_{Ln} and Z_{Sn} are derived as follows:

$$Z_{Ln} = \frac{Z_{Tn}}{\tan\theta_{Ln}} \quad , \tag{1}$$

$$Z_{Sn} = \frac{Z_{Tn} \cdot \tan\theta_{Sn}}{1-\tan^2\theta_{Ln}} \quad . \tag{2}$$

where Z_{Tn} is the impedance of the $\lambda_g/4$ transmission line as the n'th inverter and Z_{Ln}, Z_{Sn}, θ_{Ln}, and θ_{Sn} are impedances and electrical lengths of the n'th line and stub, respectively.

Also, the $\lambda_g/4$ short-stub BPF using the tapped-line geometry can be designed as shown in Fig. 2(a). The impedance and electrical lengths for the line and open/short-stub can be calculated from [6]. Especially, the electrical length of the transmission line as the k'th inverter, θ_{Tk} is 90°. For comparison, the stub and transmission line as the inverter for the $\lambda_g/4$ short-stub BPF is designed 50 Ω. i.e. $Z_{OSk} = Z_{SSk} = Z_{Tk} = 50$ Ω. To demonstrate the feasibility and usefulness of the design, the short-stub BPF using the tapped-line geometry is designed the 5th order chebyschev prototype filter with 0.01dB ripple and 10% bandwidth at the center frequency of 2.4 GHz.

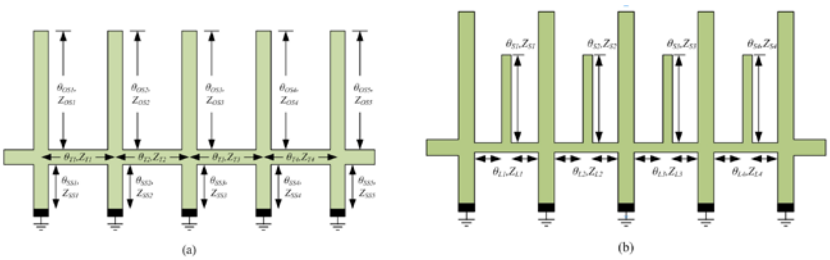

Fig. 2. Structure of (a) the $\lambda_g/4$ short-stub BPF with 5^{th} order and (b) the proposed harmonic suppressed BPF with the T-type inverter

Fig. 2(b) shows the structure of the suggested harmonic suppressed BPF. Each $\lambda_g/4$ transmission line in Fig. 2(a) is alternated the T-type inverter. In order to suppress the second and third-mode harmonics, two different T-type inverters with different electrical lengths of the open-stub are designed as shown in Fig. 2(b). Parameters in Fig. 2(b) can be obtained by using Eq. (1) and (2).

3 Manufacturing and Results of Harmonic Suppressed Short-Stub Bandpass Filter

In this paper, the harmonic suppressed short-stub BPF with the T-type inverter is design with the bandwidth of 10% at the center frequency of 2.4 GHz using EM simulator. To validate the design concept, two filters are built on a copper coated teflon substrate with a dielectric constant of 2.54, a height of 0.54 mm, and a metal's thickness of 0.017 mm. In the experiment, the measurement has been done with an Agilent 8510C network analyzer using standard SMA connector. Fig. 3 shows the photograph for the proposed harmonic suppressed short-stub BPF. The size of the proposed short-stub BPF is 24.51×73.44 mm^2.

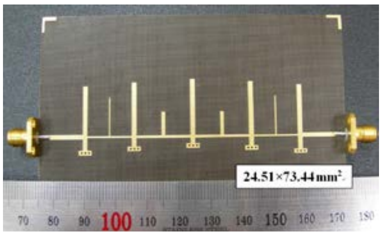

Fig. 3. Fabricated harmonic suppressed short-stub BPF with T-type inverter

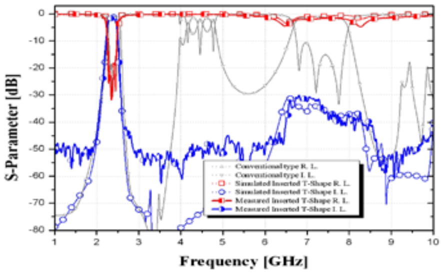

Fig. 4. Simulated and measured results of frequency responses for the harmonic suppressed short-stub BPF with T-type inverter

The overall simulated and measurement results of the harmonic suppressed $\lambda_g/4$ short-stub BPF with inserted T-type inverter agree very well as shown in Fig. 4. From the simulation results of the Fig. 4, the conventional short-stub BPF has the higher mode harmonics, however, the proposed short-stub BPF with T-type inverter has the characteristic of the second and third mode harmonics suppression up to 10 GHz. Also, the proposed short-stub BPF with T-type inverter is simulated with an insertion loss of 1.21 dB and a return loss of less than 20 dB at the center frequency 2.38 GHz. While the measurement data show the insertion loss of 1.64 dB and return loss of 20 dB at the center frequency of 2.37 GHz with suppressed harmonics under 30 dB up to 10 GHz by the additional open stubs of the T-type inverter.

4 Conclusions

In this paper, a simplified design method of the harmonic suppressed short-stub BPF for ISM applications is proposed by using the conventional short-stub BPF with inserted T-type inverter. The T-type inverter can be designed by the equivalent circuit of the quarter wavelength transmission line and can be suppressed harmonics by the open-stub. Proposed short-stub BPF has two different T-type inverters and the second and third-mode harmonics of the proposed short-stub BPF are rejected.

Also, the suggested short-stub BPF design allows narrower bandwidth and suppressed the second and third mode harmonics implementation compared to the conventional short-stub BPF which is typically provided. The proposed filter is easily implemented and integrated with other devices and circuits.

References

1. E. G. Cristal, "Tapped-line coupled transmission lines with applications to interdigital and combline filters," IEEE Trans on Microwave Theory Tech 23 (1975), 1007-1012.
2. J. S. Wong, Microstrip Tapped-Line Filter Design, IEEE Trans Microwave Theory Tech 27 (1979), 44-50.
3. T. S. Yun, T. U. Hong, B. Lee, J. J. Choi, J. Y. Kim, K. B. Kim, and J. C. Lee, "A new band-pass filter design with tapped-line using J/K-inverter," Microwave and Optical Tech Lett 49 (2007) 1253-1256.
4. J. S. Hong and M. J. Lancaster, Microwave filters for RF/microwave applications, Wiley, 2001.