New Compact Bandpass Filter Using Microstrip $\lambda/4$ Resonators with Open Stub Inverter

Jae-Ryong Lee, Jeong-Hoon Cho, and Sang-Won Yun

***Abstract*—In this letter, a novel bandpass filter using microstrip quarter-wavelength resonators is proposed. The proposed filter consists of the open stub inverter between quarter-wavelength resonators, which results in compact design as well as low loss. The tapped open stub not only works as a K-inverter but also introduces an attenuation pole. The attenuation pole can be located at upper or lower side of the passband by adjusting the open stub length. Two-pole Chebyshev bandpass filter is designed and tested at 1.99 GHz. Four-pole bandpass filter of elliptic- type performance is also designed and tested at 2.015 GHz.**

***Index Terms*—Bandpass filter, K-inverter, quarter-wavelength resonator.**

I. INTRODUCTION

MODERN personal communication systems require miniaturized high-performance bandpass filter having low insertion loss and high selectivity in the passband. Microstrip line bandpass filters of low insertion loss must be designed by direct coupling, not gap coupling, because of the radiation loss. The selectivity of bandpass filters can be improved by introducing the elliptic-function response. The conventional elliptic-function bandpass filters having high selectivity use open-loop resonators [1], [2] or ring resonators [3], where the lengths of resonators are either a half-wavelength or a wavelength. Therefore, the size of these resonators is too large to design miniature bandpass filters for personal communication systems. In order to apply to mobile communication systems, we propose a novel resonator, which contributes to compact configuration. The conventional $\lambda/4$ microstrip line resonator of combline or interdigital bandpass filter is shorted to ground, while the proposed filter configuration does not require the line being shorted to ground. Therefore, the proposed filter is simpler than the combline or interdigital bandpass filters in fabrication.

In this letter, we will describe the filter design and demonstrate the measured performances of two- and four-pole bandpass filters, based on the proposed configuration.

II. PROPERTIES OF FILTER

The two-pole bandpass filter that employs the proposed configuration is shown in Fig. 1. This two-pole bandpass filter is a primary structure, which is composed of two microstrip quarter-wavelength resonators and a tapped open stub. The quarter-wavelength resonators need not be shorted to ground, because the tapped open stub replaces the stub shorted to the ground.

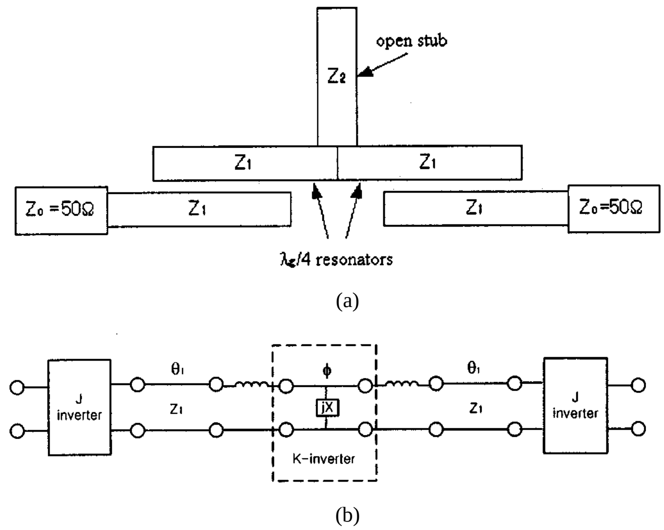

Fig. 1. Two-pole bandpass filter. (a) The layout. (b) The equivalent circuit.

The tapped open stub has several important properties. It works as a K-inverter between the quarter-wavelength resonators. Also, by changing the length of a tapped open stub, one can control the notch frequency in the stopband. As the characteristic impedance Z2 increases, the attenuation pole is located closer to the passband edge.

In the bandpass filter design, The characteristic impedances Z1 and Z2 of the resonator and the open stub inverter, respectively, are selected by location of the attenuation pole as well as the filter bandwidth, because the value of inverter is defined by the characteristic impedances as well as the length of the stub, and the frequency of attenuation pole is defined by electrical length of the stub.

The designed four-pole bandpass filter that has elliptic-type performance is composed of two-stage bandpass filters having attenuation poles at upper and lower side of the passband edge. The design of proposed bandpass filter is simpler than the conventional elliptic-function bandpass filter, and the filter is more compact because quarter-wavelength resonators are used.

III. EXPERIMENTAL PERFORMANCE

Experimental bandpass filters were designed and tested. The bandpass filters were fabricated on PTFE substrate with a relative dielectric constant of 2.6 and a thickness of 0.508 mm. The characteristic impedance of the microstrip lines used as resonators and open stub is 61 Ω.

The two-pole bandpass filters have been built with a center frequency of 1.99 GHz and 60 MHz bandwidth. The layout, sim-

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The authors are with the Electronic Engineering Department, Sogang University, Seoul 100–611, Korea (e-mail: ljr@eemic.sogang.ac.kr).

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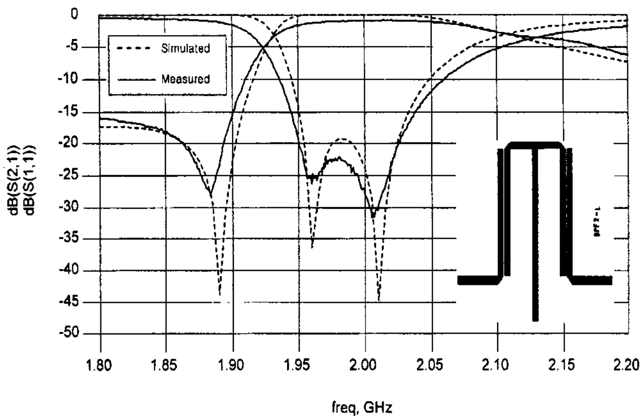

Fig. 2. Layout and responses of two-pole bandpass filter having a notch at lower side of the passband.

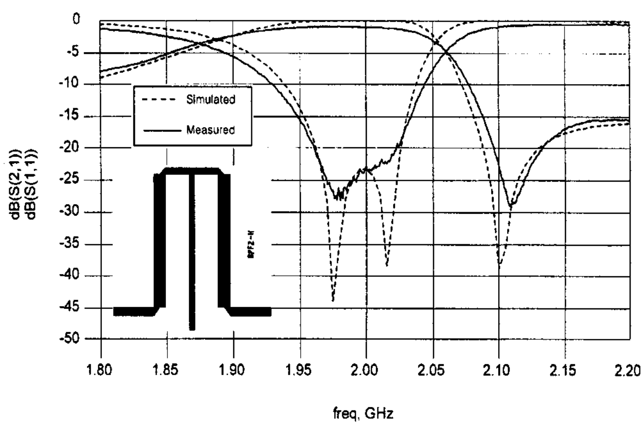

Fig. 3. Layout and responses of two-pole bandpass filter having a notch at upper side of the passband.

ulated and measured bandpass filter performances of two-pole bandpass filter that has a notch at lower side from the passband are shown in Fig. 2. The size of filter is 12.93×28.2 mm. Coupling gap size is 0.125 mm. The passband insertion loss is about 1.32 dB and the location of attenuation pole is 1.885 GHz.

The layout, simulated and measured bandpass filter performances of two-pole bandpass filter with the notch frequency at upper side from the passband are shown in Fig. 3. The passband insertion loss is about 1.2 dB and the location of attenuation pole is 2.11 GHz. The size of filter is 13.26×25.7 mm. Coupling gap size is 0.115 mm.

The four-pole bandpass filter has been built with a center frequency of 2.015 GHz and 100 MHz bandwidth. Fig. 4 shows the layout of the bandpass filter, the simulated and measured filter performances. The filter has a passband insertion loss of 2.4 dB and the locations of attenuation pole are at 1.9 GHz and 2.13 GHz. The size of filter is 24.81×31.45 mm. Coupling gap sizes are 0.08 mm, and 0.85 mm, respectively.

Fig. 5 shows spurious response of four-pole filter. Two quarter-wavelength resonators with direct coupling cause the spurious responses at the even order harmonic frequencies, while they are canceled at odd order harmonic frequencies, because the tapped open stub has attenuation poles at odd order harmonic frequencies.

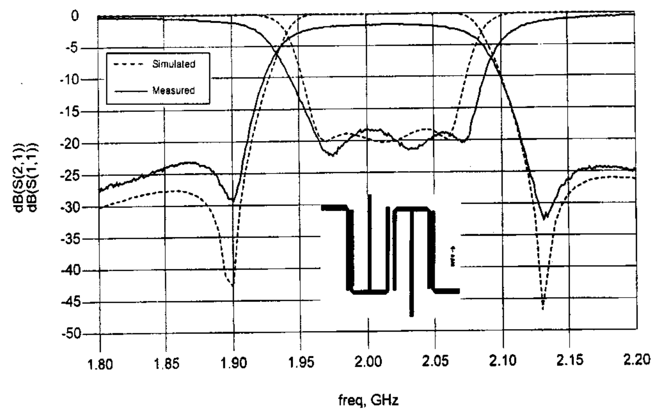

Fig. 4. Responses of four-pole bandpass filter.

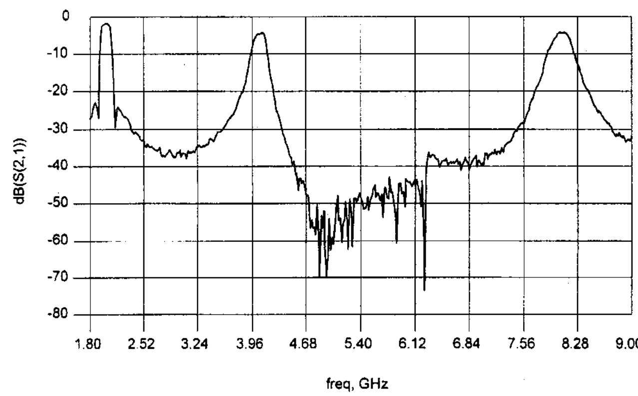

Fig. 5. Measured spurious characteristics of four-pole bandpass filter.

IV. Conclusion

We have proposed a novel bandpass filter using microstrip quarter-wavelength resonators with open stub inverter. Two- and four-pole bandpass filter based on this configuration have been designed, built and tested. The attenuation pole can be located near the passband by adjusting the stub length. The proposed four-pole elliptic-type bandpass filter is more compact and simpler in design than the conventional elliptic-function bandpass filter. The other advantages of the proposed bandpass filters are: the resonators need not be shorted to ground, and the bandpass filter has low loss because direct coupling is used.

This bandpass filter is believed to be quite useful for applications in mobile communication systems.

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