A Narrow Bandwidth Microstrip Band-Pass Filter with Symmetrical Frequency Characteristics

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ABSTRACT— This letter proposes a band-pass filter (BPF) with two transmission zeros based on a combination of parallel coupling and end coupling of half-wave transmission lines. The fabricated BPF exhibited a narrow bandwidth and two transmission zeros near the pass-band due to the end-coupled and shielding waveguide. At the center operation frequency of 60 GHz, the 20 dB bandwidth of the BPF is 1.0 GHz, which is almost 2% of the center operation frequency, and the insertion loss is 3.12 dB. Two transmission zeros reach approximately 40 dB at 58.5 and 62.5 GHz. The simulation results almost agree with the measured results.

Keywords— Band-pass filter (BPF), parallel-coupled, end-coupled.

I. Introduction

Recently, the millimeter wave band-pass filter has been studied and exploited extensively as a key circuit block in home networks, telematics, intelligent transport systems, and satellite high-speed internet.

A cost-effective 60 GHz module has been reported for high-speed internet and gigabit home-link systems [1]. A 60 GHz image rejection filter has been developed using a high-resolution low-temperature co-fired ceramic screen-printing process [2]. The compact micro-strip band-pass filter with two transmission zeros has been proposed [3]. The design methods for a parallel-coupled line filter with arbitrary image impedance have been reported [4], [5]. The synthesis and design of a suspended substrate capacitive gap-parallel-coupled line band-pass filter with one transmission zero has been developed [6]. Band-pass filters with an 8th order dual-mode elliptic integral function band-pass filter have been developed [7]. These filters did not satisfy all the requirements including compact size, narrow bandwidth, and two transmission zeros near the pass-band.

In this letter, we describe a band-pass filter (BPF) used in high-speed wireless communication systems. These systems require a BPF with two transmission zeros near the pass-band and a narrow bandwidth. Also, we need the advantage of the in/out termination admittances of the BPF being easily controlled irrespective of the degree of the dielectric constant. Therefore, we are proposing a BPF with two transmission zeros based on a combination of parallel coupling and end coupling of half-wave transmission lines. We designed a BPF using commercial software, HFSS (High Frequency Structure Simulation). The BPF was fabricated and measured.

II. Filter Design

A narrow bandwidth micro-strip BPF with symmetrical frequency characteristics is composed of three half-wave transmission line resonators, 50 Ω transmission lines, and an input/output finite ground coplanar waveguide (FGCPW) as shown in Fig. 1.

The presented BPF topology is based on two parallel transmission lines with image arbitrary admittance as given by D. Ahn [4] and a combination of parallel-coupled line with end-coupled line as given by E.Hanna [6] and Isabel Ferrer [2]. This BPF is made from an alumina ceramic substrate ($\varepsilon_r = 9.4$, tan $\delta = 0.0005$), electric conductors, and a shielding waveguide.

Here, admittance is easily controlled irrespective of the degree of the dielectric constant because arbitrary image admittance Y_1 is used; the characteristic admittance is Y_0.

Figure 2 shows the equivalent circuit of Fig. 1. The

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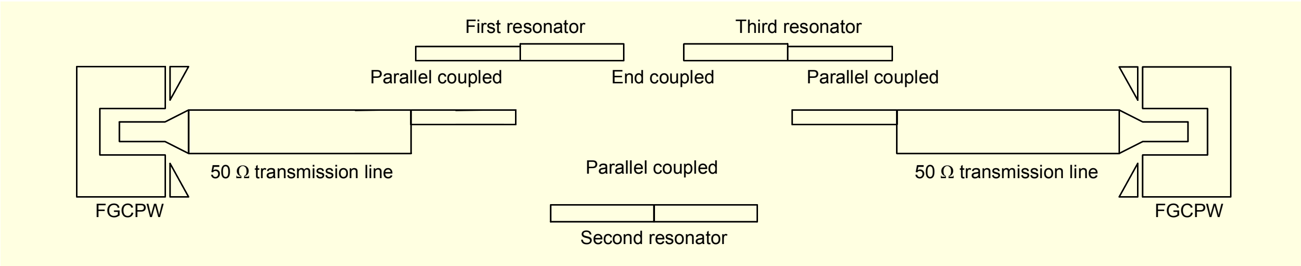

Fig. 1. Schematic layout of BPF.

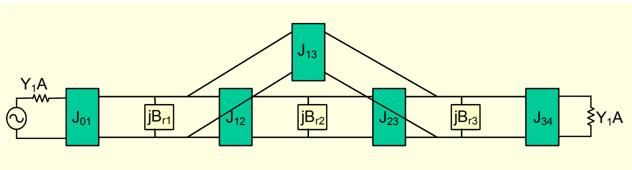

Fig. 2. Equivalent circuit of Fig. 1

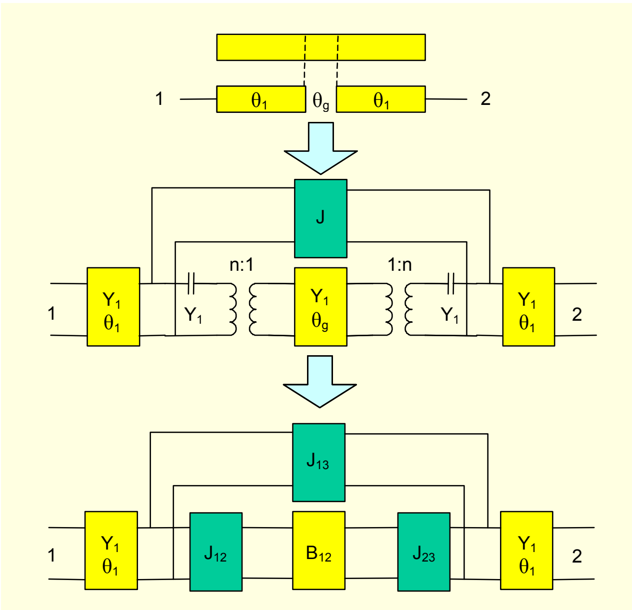

Fig. 3. Equivalent circuit of the gap-parallel coupled lines of Fig.2.

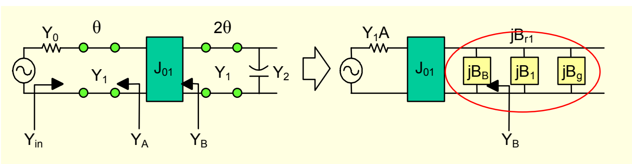

Fig. 4. Equivalent circuit of the first resonator section of Fig. 2.

equivalent circuit of the first resonator section of Fig. 2 is expressed by the admittance Y_A, which looks to the input admittance Y_{in}, and the admittance Y_B, which looks to the J_{01}-inverter as shown in Fig. 4. Figure 3 shows the equivalent J-inverter circuit end-coupled line section of Fig. 2, between the first resonator and third resonator.

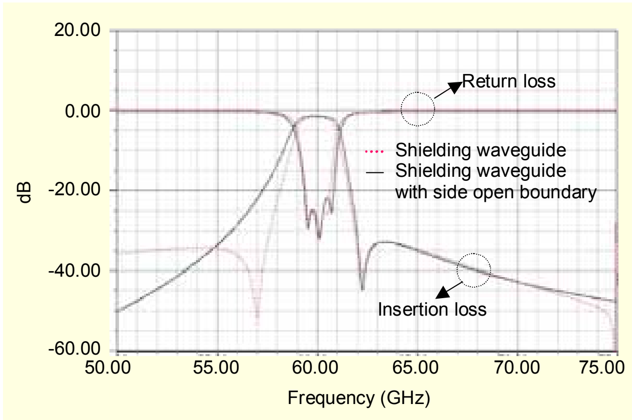

Fig. 5. Simulation results (HFSS) of BPF.

In Figs. 2 and 4, the susceptance of the first and third resonators are expressed by

$$B_1(\omega) = \frac{J_{01}^2}{Y_1} \cdot X\left(1 - \frac{1}{A^2}\right) + 2XY_1, \tag{1}$$

where

$$X = \frac{\pi}{2}\left(\frac{\omega - \omega_o}{\omega_o}\right), \quad A = \frac{Y_1}{Y_o}.$$

In Figs. 2 and 3, the susceptance of the second resonator (electrical length $2\theta = 2\theta_r + \theta_g = \lambda/2$) is expressed by

$$B_2(\omega) = Y_1\pi\left(\frac{\omega - \omega_o}{\omega_o}\right). \tag{2}$$

Therefore, we simulated a BPF by HFSS based on the finite elements method: one has a micro-strip BPF in the shielding ground with a side open boundary, and the other has a micro-strip BPF in the shielding waveguide. In Fig. 5, we can say that the transmission zero on the above pass-band agreed with the simulation results of the micro-strip BPF in the shielding ground with the a side open boundary as well as in the shielding waveguide, which proves that the transmission zero is due to being an end-coupled line. But the transmission zero on the below pass-band differed from the simulation results, which estimate that the transmission zero is due to the shielding waveguide; the inner shielding waveguide size is 4.0 × 2.0 × 1.0 mm^3.

III. Experimental Results

The BPF was fabricated on an alumina ceramic substrate with a relative dielectric constant of 9.6 and a thickness of 0.2 mm. The measurement was carried out on an HP 8510C network analyzer. As can be seen from Fig. 6, at the center operation frequency of 60 GHz, the 20 dB bandwidth of the BPF is 1.0 GHz, which is almost 2% of the center operation frequency. Two transmission zeros reach approximately 40 dB at 58.5 and 62.5 GHz. The insertion loss is less than 3.24 dB from 59.5 to 60.5 GHz, and the minimum of insertion loss is 3.12 dB. The simulation results almost agree with the measured results. Some discrepancy between them is still observed due to the unexpected surface roughness of the substrate and radiation loss in the port section of the measurement. The insertion loss of the measurement was larger than that of the simulation. A summary of the simulation and experimental results for the narrow bandwidth BPF is shown in Table 1.

Figure 7 shows a photograph of the fabricated BPF. The size

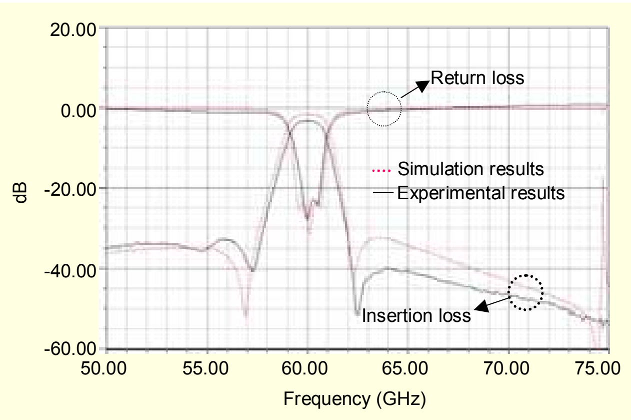

Fig. 6. Experimental and simulation results (HFSS) of BPF with shielding waveguide.

Table 1. Experimental and simulation results (HFSS) of BPF with shielding waveguide.

	Insertion loss (dB)	Return loss (dB)	Transmission zeros (dB)	
			@58.5 GHz	@62.5 GHz
Simulation	1.62	27.88	35	42
Measurement	3.12	22.87	37	52

Fig. 7. Photograph of a fabricated BPF.

of the filter is 4 × 2 × 0.2 mm^3. Both the width and height of the shielding waveguide are very important. The dimensions of the shielding waveguide must be sufficiently small to avoid propagation of the waveguide mode within the shielding waveguide because a large size can cause unwanted coupling.

IV. Conclusions

We have developed a BPF with two transmission zeros based on a combination of parallel coupling and end coupling of half-wave transmission lines. The used BPF topology is based on two parallel transmission lines with image arbitrary admittance and a combination of a parallel-coupled line with an end-coupled line. And the fabricated BPF exhibited a narrow bandwidth and two transmission zeros near the pass-band due to the cross coupling and shielding waveguide. Therefore, the BPF can be used in high-speed wireless communication systems.

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