Uniplanar Compact Wideband Bandstop Filter

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***Abstract*—A uniplanar wideband bandstop filter is proposed using two bended open-end stubs. The proposed filter consists of the bended connecting line of $\lambda_g/2$ between two bended $\lambda_g/4$ stubs, which results in wideband design with a rejection bandwidth of 90% at 2.05 GHz. Further, the connecting line and stubs have the same characteristic impedance. The proposed filter compared to the conventional one is also more compact. The area of the novel filter is $(\lambda_g/4)^2$ at the center frequency of the stopband, while the area of the filter realized using the nonbended stubs and connecting line is $2(\lambda_g/4)^2$ for the same stopband characteristics.**

***Index Terms*—Uniplanar filter, compact size, wideband bandstop filter.**

I. Introduction

In RECENT years, uniplanar transmission lines such as coplanar waveguides (CPW), coplanar strip (CPS), and slot line (SL) have become preferable over conventional microstrip lines with an increasing use in monolithic or hybrid integrated circuit applications at microwave frequencies, owing to their small dispersion, low radiation, easy integration with lumped elements or active devices, high circuit density, and no need for via holes. Many attractive components using uniplanar structures have been developed [1]–[4]. However, uniplanar wideband bandstop filters to reject out-of-band frequencies have not been sufficiently considered in microwave literature, whereas bandstop circuits are one of the most important parts of many passive and active microwave and millimeter-wave devices employed to suppress the harmonics.

Some frequency bands in microwave applications can be filtered using quarter-wave open-end or short-end stubs along a transmission line or stepped-impedance structures, but these circuits are typically narrow-band with a spurious passband in stopband and require large circuit layout size. PBG structures have been employed as an alternate to overcome these problems in microwave applications [5], [6]. However, practical application of a PBG structure usually has difficulty in accommodating its physical size since the period of a PBG lattice has to be a half wavelength at the stopband frequency, while the proposed structure occupies a surface area of $(\lambda_g/4)^2$, where λ_g is the guided wavelength at the center frequency of stopband. Moreover, uniplanar PBG structures also have not been sufficiently considered [7], [8]. In this study, a novel uniplanar bandstop filter is proposed using two bended $\lambda_g/4$ open-end stubs and a bended $\lambda_g/2$ connecting line between these stubs. The proposed filter has the merits of compact size, wideband, and uniplanar feature.

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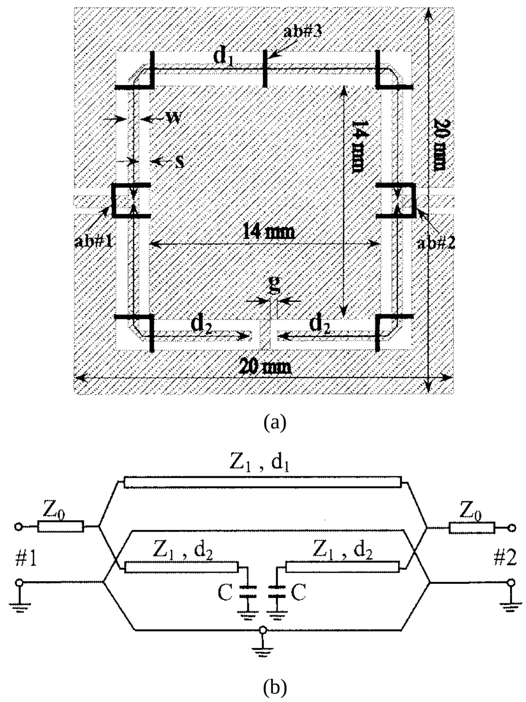

Fig. 1. Uniplanar wideband bandstop filter: (a) configuration ($w = 0.5$ mm, $s = 0.25$ mm, $g = 0.25$ mm, $d_1 = 30$ mm, and $d_2 = 15$ mm); (b) equivalent transmission-line model ($Z_0 = 50\ \Omega$, $Z_1 = 56.3\ \Omega$, $d_1 = \lambda_g/2$, $d_2 = \lambda_g/4$, and $C = 11.345$ fF).

II. Filter Structure and Its Equivalent Circuit

The wideband CPW bandstop filter structure is shown in Fig. 1(a). The structure is composed of two bended open-end stubs and a bended connecting line and is in form of the square open-loop. The bended open-end stubs have a length of $d_2 = \lambda_g/4$ at the center frequency of stopband. Unlike the conventional $\lambda_g/4$ filter, the connecting line between the stubs has a length of $d_1 = \lambda_g/2$ to obtain the wide stopband. The bending of the shunt stubs and connecting line makes the bandstop filter more compact with respect to the conventional (nonbended) one. The equivalent transmission-line model for the bandstop filter is shown in Fig. 1(b). For equivalent circuit, CPW transmission line sections, compensated bends, and CPW open- ends are used. The open-end stubs have the same characteristic impedance as the connecting line. Their characteristic impedances are $Z_1 = 56.3\ \Omega$ ($s = 0.25$ mm, $w = 0.5$ mm). Input and output CPW feed lines have a characteristic impedance of $Z_0 = 50\ \Omega$. The impedances were calculated using a full-wave em simulator [9].

As is well-known, the coupled-slotline mode is generated in CPW bends due to the path length difference of the slots. Air-bridges were placed at the CPW feed lines and bends in order to suppress the unwanted coupled-slotline mode, which tends to radiate, for obtaining an adequate filter performance. Since air-bridges introduce an additional capacitance, which degrades the performance of the bend, the compensated CPW bend described in [10] was used to compensating for the increase in capacitance due to the air-bridges.

On the other hand, the capacitance value of CPW open end was calculated as $C = 11.345$ fF using design equations given in [11]. It can also be obtained by fitting the measured S-parameters of the open end. In such a case, the fitted value of open-end capacitance was found to be about the same value as calculated one using equations in [11]. As a result, the frequency response calculated using the equivalent transmission-line model illustrated in Fig. 1(b) is shown in Fig. 2. The filter response has arithmetic symmetry, such as that of conventional $\lambda_g/4$ resonator filters [12]. The proposed filter has a rejection bandwidth of 90% at center frequency of 2.05 GHz, whereas the conventional $\lambda_g/4$ filter has a bandwidth of 60% at the same center frequency.

III. Simulated and Measured Results

The wideband bandstop filter was designed with a rejection bandwidth of 90% at a center frequency of 2.05 GHz using a full-wave em simulator [9]. The experimental bandstop filter circuit was fabricated on an RT/Duroid 6010 substrate with a relative permittivity of $\varepsilon_r = 10.2$ and thickness of $h = 1.27$ mm. During testing, the filter circuit was connected to an HP 8720C Network Analyzer, which is calibrated from 1 to 8 GHz. Standard SMA connectors, which represent short circuits for coupled-slotline mode, were used in measurements. The measurements were performed on unshielded structures. Moreover, the air-bridges at the filter's discontinuities were used to suppress the coupled-slotline mode from propagating on the CPW line. Frequency response for the proposed bandstop filter has been simulated using a full-wave em simulator [9]. Simulated response presents an excellent agreement with theoretical response based on the transmission-line model, as shown in Fig. 2. Moreover, Fig. 2 shows the measured filter performance as well. Measured response presents also an excellent agreement with both simulated and theoretical responses. The filter has a rejection bandwidth of 90% at 2.05 GHz. The minimum return loss in the stopband was measured as 0.33 dB; the minimum insertion loss in the lower passband and the upper passband was measured as 0.39 and 1.36 dB, respectively.

It should be mentioned that the repetition of each air-bridge in the filter structure was verified by measuring several filters with the same dimensions. Additionally, the proposed filter has been realized using the same structure without air-bridges at the compensated bends and air-bridge (ab#3) at the middle of connecting line of $\lambda_g/2$ to avoid additional air-bridges. The measured S-parameters of the bandstop filters without these air-bridges are compared in Fig. 3. These results are almost the same as shown in Fig. 2, except for resonance peaks observed at 4.6 and 5.4 GHz in the case without air bridges at the bends and air-bridge ab#3. Our measurements have shown that the resonance at 5.4 GHz is mainly a result of the absence of air-bridges at the bends, while the resonance at 4.6 GHz is due to the absence of air-bridge ab#3. These resonances are due to the radiation loss attributed to the excited coupled-slotline mode. It should be mentioned that the filter performance was not affected by the absence of the air-bridges ab#1 and ab#2. The reason is that SMA connectors used in measurements represent short circuits for coupled-slotline mode and, thus, the other air-bridges at the feeds, which need to be used for an adequate performance, tend to equalize the potential of the ground planes. As a result, it seems that the coupled-slotline mode is suppressed with adding air-bridges at compensated bends and air-bridge ab#3 and, hence, the resonances at 4.6 and 5.4 GHz disappear due to the significant decrease in the radiation loss.

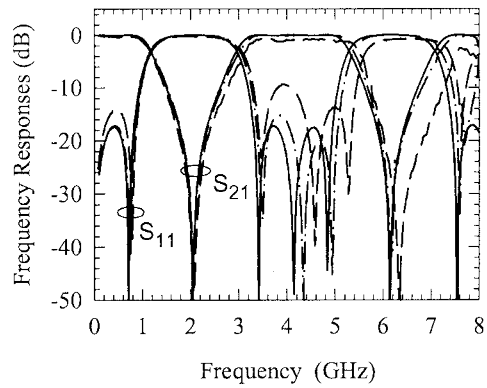

Fig. 2. Comparison of theoretical performance (solid line) based on equivalent transmission-line model, simulated performance (dash-dotted line), and measured performance (dashed line) for proposed uniplanar wideband bandstop filter with connecting line of $\lambda_g/2$.

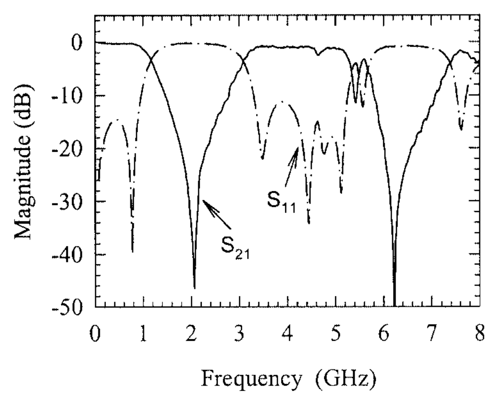

Fig. 3. Measured performance of proposed uniplanar wideband bandstop filter without air bridges at the compensated bends and air-bridge ab#3.

IV. Conclusion

A novel uniplanar bandstop filter has been proposed using two bended open-end stubs and a bended connecting line between these stubs, which have the same characteristic impedance as that of connecting line. The measured performance is in excellent agreement with both simulated and theoretical results. The new filter has an area of $(\lambda_g/4)^2$ at the center frequency of the stopband, which is 50% smaller compared to the size of one with the nonbended connecting line and stubs for the same stopband characteristics. The proposed filter has both a reduced-size and a wide stopband of 90% as well as easy fabrication. This uniplanar filter can also be found application in broadband receiving systems.

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