Novel Low-Pass Filter for Broad-band Spurious Suppression

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Abstract — **Novel microstrip-type low-pass filters are proposed to effectively suppress spurious response in stop-band. The proposed low-pass filter employs an open stub microstrip inserted by thin or thick film resistors in the place of a conventional open stub microstrip. The proposed low-pass filters was shown to suppress the spurious response by more than 20~40 dB compared with conventional mirostrip low-pass filters.**

I. INTRODUCTION

Many applications including mixers or oscillators require low-pass filtering to suppress the harmonic components or unwanted signals. Low-high impedance low-pass filters and open stub low-pass filters have been commonly used for this purpose. However, due to the periodicity of the distributed microsrip lines with respect to frequency, these filters show poor spurious response in stop-band.

In order to solve such a problem, some techniques have been introduced [1-4]. Sheen proposed a low-pass filter with low spurious response by means of connecting lumped elements to microstrips in parallel, which can avoid the periodicity of the harmonic frequencies of microstrip [1]. Low-pass filters using PBG or DGS is another approach to these applications [2-4]. These approaches improve the spurious response in the specific frequency band associated with the shape and size of ground pattern. However, beyond the specific frequency band, its effectiveness may be disappeared or another spurious characteristic may appear out of the specific rejection band.

The object of this paper is to present novel low-pass filters to effectively eliminate spurious response that is generated by a periodicity of a transmission line with respect to frequency. Two demonstrated low-pass filters showing the broad-band spurious suppression are addressed.

II. THE CONVENTIONAL LOW-PASS FILTER

Fig. 1 shows a conventional open stub low-pass filter. The cutoff frequency is designed to be 2.5 GHz. To obtain more steep skirt response near the pass-band edge, an attenuation pole is inserted in stop-band, which is realized in open-stub microstrip, L4, shown in Fig. 1. In this configuration, open stub microstrip operates as a capacitive element and high impedance microstrip as an inductive element in pass-band. The filter was implemented on an alumina substrate with a thickness of 0.635mm. Within the low frequency band, the filter shown in Fig. 1 shows similar filtering response to the prototype low-pass filter composed of ideal lumped elements. In high frequency band, however, the periodicity introduced by distributed microstrip lines makes this filter behave in a different way to the prototype low-pass filter. This distributed-circuit nature causes spurious response in stop-band.

Fig. 2 and Fig. 3 show the simulated and measured characteristics of the filter shown in Fig. 1, respectively. As shown in Fig. 2 and Fig. 3, unwanted spurious characteristics appear at 4.96GHz and 6.8GHz in stop-band. The spurious characteristics in stop-band are generated from the distributed nature of employed open stub microstrips.

III. THE PROPOSED LOW-PASS FILTER

The proposed low-pass filter corresponding to Fig. 1 is shown in Fig. 4. This filter employs modified open-stub microstrips where thick film resistors are appropriately loaded. In the proposed filter, a series-connected microstrip and an open stub microstrip inserted by thick film resistance are operated as an

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inductor and a lossy capacitor in pass-band, respectively. The function of a thick film resistor inserted in an open-stub microstrip is to purposely degrade the quality factor in the high frequency band, and thus to mitigate the spurious responses in stop-band. In Fig. 4, the sheet resistance is 25 Ω per unit square. The location of the distributed resistor in an open-stub microstrip may be controlled according to the actual frequencies where the spurious signals are present. The DC resistance values used in Fig. 4 are as follows.

$$L1 : 5\Omega,\ L2 : 5\Omega,\ L4 : 14\Omega,\ L5 : 31\Omega$$

Fig. 5 and Fig. 6 show the simulated and measured characteristics of the proposed low-pass filter shown in Fig. 4. The simulated and measured performances are summarized in Table I and Table II, respectively. Compared with the conventional low-pass filter shown in Fig. 1, the proposed low-pass filter shows about 20 dB of improvement in stop-band spurious characteristic at the cost of 0.5dB increase in pass-band insertion loss.

Fig. 7 shows another example of the proposed low-pass filter, in which the thin film resistors are inserted in radial open stub. The proposed low-pass filter is implemented on an alumina substrate with a thickness of 0.38mm. Sheet resistance of 25 Ω per unit square is used. The inserted DC resistance values are all the 10 Ω. Fig. 8 shows simulated results for the filter with/without resistors shown in Fig. 7. The proposed radial stub low-pass filter employing resistors shows the significant spurious enhancement of 40dB over a conventional radial stub low-pass filter. Fig. 9 shows the measured result of the proposed radial stub low-pass filter.

Table I. Comparison of the simulated characteristics of a conventional LPF and the proposed LPF

	A conventional LPF	The proposed LPF
Insertion Loss	-0.2dB @ 1.9GHz	-0.6dB @ 1.9GHz
Spurious Response	-10.8dB @4.96GHz -29.7dB @6.8GHz	-32.0dB @ 4.3 GHz -32.5dB @ 6.48 GHz

Table II. Comparison of the measured characteristics of a conventional LPF and the proposed LPF

	A conventional LPF	The proposed LPF
Insertion Loss	-0.37dB @ 1.9GHz	-0.87dB @ 1.9GHz
Spurious Response	-9.8dB @4.92GHz -26.6dB @6.72GHz	-44.9dB @ 4.92 GHz -31.0dB @ 6.72 GHz

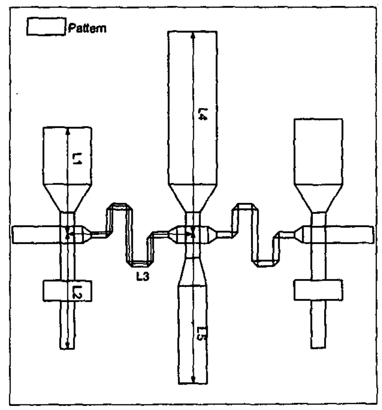

Fig. 1. A conventional open stub microstrip filter (circuit size : 13 mm X 14 mm)

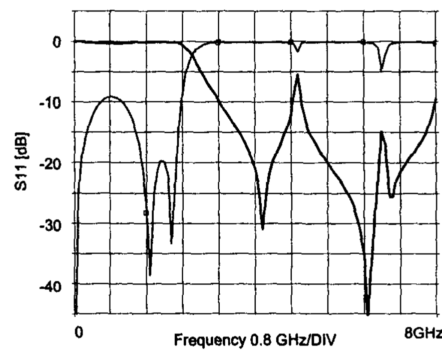

Fig. 2. Simulated response of a conventional open stub microstrip filter shown in Fig. 1.

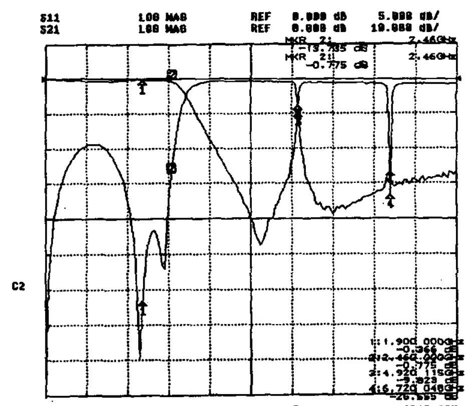

Fig. 3. Measured response of a conventional open stub microstrip filter shown in Fig. 1.

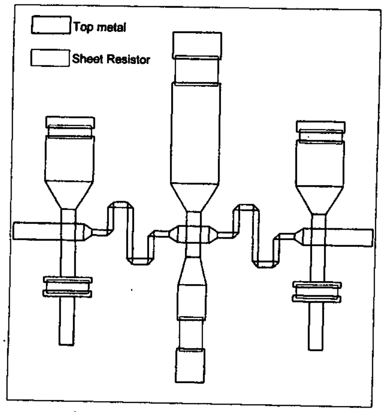

Fig. 4. The proposed open stub microstrip filter (circuit size 13 mm X 14 mm)

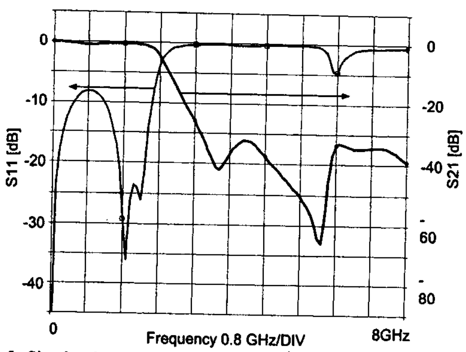

Fig. 5. Simulated response of the proposed open stub microstrip filter shown in Fig. 4.

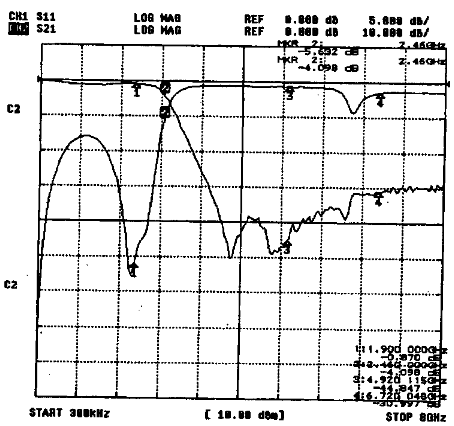

Fig. 6. Measured response of the proposed open stub microstrip filter shown in Fig. 4.

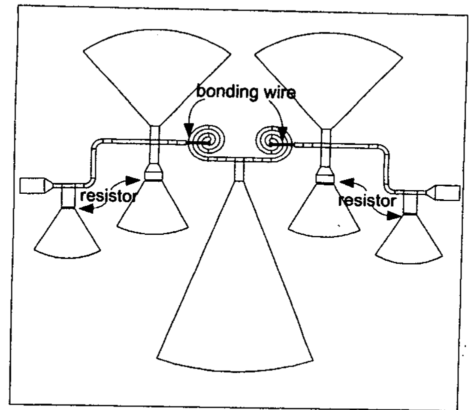

Fig. 7. Radial stub microstrip low-pass filter (circuit size 10 mm X 10 mm).

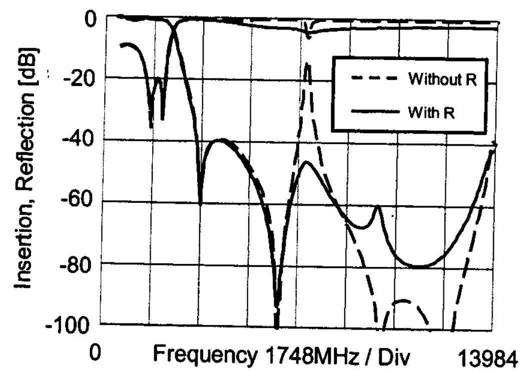

Fig. 8. Simulated results of radial stub low-pass filter. Doted and solid lines denote a conventional and the proposed low-pass filters, respectively.

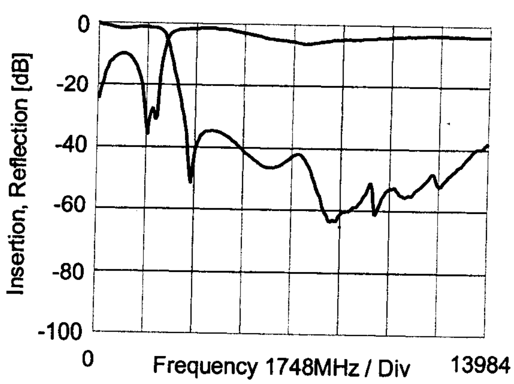

Fig. 9. Measured result of the proposed radial stub low-pass filter.

IV. Conclusion

In this paper, novel low-pass filters to efficiently suppress spurious response in broad-band have been proposed. The proposed filters with a cutoff frequency of 2.5GHz show a 20~40dB spurious suppression enhancement compared with conventional open stub low-pass filters. The demonstrated low-pass filters show a good spurious response up to 14GHz. The proposed low-pass filters can be used as a broad-band spurious signal rejection filter such as a harmonic rejection filter of a local oscillator.

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