Improvement of Stopband Property of Parallel Coupled Microstrip Bandpass Filters by Use of Open Stubs

Maryam Jaldi and Majid Tayarni

Abstract—**In this paper a novel method is presented for suppressing spurious response of parallel coupled microstrip filters. This technique is based on introducing open stubs to the filter. A third order filter is presented with central frequency at 3GHZ. The filter insertion is less than 1 dB. The harmonic suppression at the first and second harmonic is more than 20 dB and 25 dB, respectively. The performance of the new filter is also compared with characteristic of a conventionally designed filter to highlight the advantages of the proposed designed filter.**

Index Terms—**Bandpass filer, parallel coupled, spurious response, stub.**

I. Introduction

Parallel coupled microstrip bandpass filters [1] are widely used in many wireless and microwave systems. Because they can be easily fabricated and have simple synthesis procedure [2]-[4]. Also by folding them into hairpin form, they can occupy less space [5], [6]. Also they have a wide bandwidth range [7], [8].

Despite these advantages, it suffers from poor stopband because they have spurious response at the multiple of operating frequency. Based on transmission line theory, when the electrical length of the line confirms the related equation, the resonance occurs, but at the multiple of the resonance frequency, the equations are confirmed again, so in the filter response, we have spurious response at the multiple of the operating frequency. This spurious response degrades the rejection of the systems, so we should eliminate this parasitic response.

Several techniques have been proposed to realize wide stopband and reject the first harmonic. The easiest way to overcome this problem is to cascade lowpass filter with the bandpass filter but the insertion loss of the filter will be increased and we have to design two kinds of filter.

Recently defected ground structures [9] can well suppress the spurious response, but it is difficult to design and implement. Over coupled resonator [10], can be used to extend stopband of the filter, but they have neither straight procedure nor equation to design. The other ways are cutting grooves along the microstrip lines [11] and use of lumped capacitors [12], [13].

A parallel coupled microstrip filter, also have spurious response at the third coefficient of the central frequency, this harmonic can also be legitimized by the transmission line theory. Little method has been proposed to reject multi spurious passband. In [14], over-coupled stages are used for multispurious suppression.

In this paper a simple method is presented to reject the harmonics of the parallel coupled microstrip bandpass filters. This technique requires neither change in the conventional filter design nor more complexity fabrication compared to the conventional filter. In this method, quarter wave stubs are placed symmetrically on the coupled lines to suppress the second and third harmonics.

This article is organized as followed: In Section II, a conventional parallel coupled bandpass filter is designed; next the theory of open stub resonator is explained. In Section III, by use of open stubs we extend the stopband of the filter, Section IV; demonstrate the measured response in comparison with the simulated results. Finally a conclusion is drawn in Section V.

II. Filter Design

A. Conventional Filter

The general schematic diagram of a conventional parallel-coupled microstrip bandpss filter is presented in Fig. 1. The filter is a three section chebyshev bandpass filter with central frequency of 3 GHZ and passband bandwidth of 10%. The microstrip line width is chosen as $W = 1mm$, and the characteristic impedance of the microstrip is 50Ω. The substrate used in the simulation has a board thickness of 0.635 mm, a dielectric constant of $\varepsilon_r = 2.75$, and a loss tangent of 0.002. The basic design methodology is same as the conventional filter design procedure [4]. Accordingly the dimension of the structure is illustrated in Table I, where W is the width of coupled lines and S is the space between the coupled lines and n is the number of section. Z_{0e} and Z_{0o} are even and odd mode characteristic impedance of the coupled microstrip line resonators, respectively.

Fig. 1. Conventional parallel coupled-line bandpass filter.

We should consider that above dimension is obtained after optimization to meet best response. Based on this dimension, the structure is simulated by use of AWR [15].

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TABLE I: PHYSICAL DIMENSION OF A CONVENTIONAL PARALLEL COUPLED BANDPASS FILTER

N	$Z_{0e}(\Omega)$	$Z_{0o}(\Omega)$	W(mm)	S(mm)
1,4	87.465	37.5	0.6711	0.06552
2,3	62.0725	41.969	0.8989	0.3637

The simulated frequency response of the filter is shown in Fig. 2. Central frequency of the filter is 3GHZ and it has 10% bandwidth.

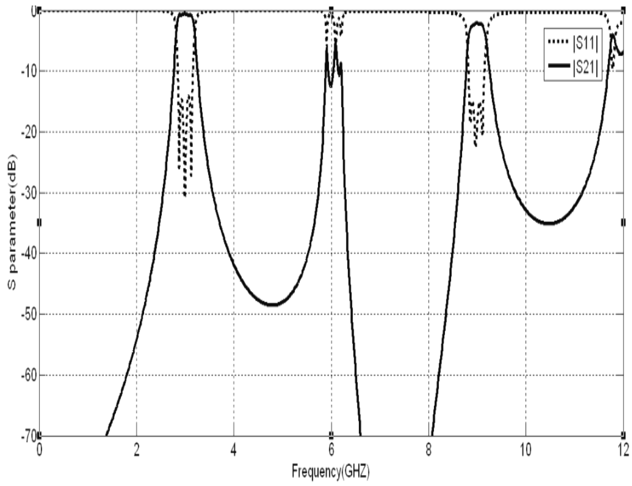

Fig. 2. Frequency response for the conventional third order parallel coupled microstrip bandpass filter.

As can be seen it has harmonics at 6 GHZ and 9 GHZ. So it has poor stopband and we should eliminate these parasitic responses. We should notice that the passband response should not change significantly.

B. Stub Loaded Parallel Coupled Microstrip Line

The distributed line resonators shown in Fig. 3 is named quarter wavelength resonator, since it is $\lambda_{g0}/4$ long, Where λ_{g0} is the guided wavelength at the fundamental resonance frequency f_0.

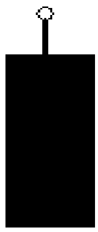

Fig. 3 $\lambda_{g0}/4$ resonator.

According to the transmission line theory, the input admittance of an open circuited transmission line having a characteristic admittance of $Yc = 1/Z_c$ and the propagation constant of $\beta = 2\pi/\lambda_g$ is given by

$$Y_{in} = jY_c \tan(\frac{2\pi}{\lambda_g} l) \quad (1)$$

Fig. 4 shows the structure of a stub loaded coupled structure. The length of stubs is $\lambda_g/4$ where λ_g is the guided wavelength at the operating frequency ($f_0 = 6\ GHZ$). The simulation results is shown in Fig. 5. As can be seen a pole is located at the vicinity of $f = 6GHZ$.

Fig. 4. The structure of a stub loaded coupled line.

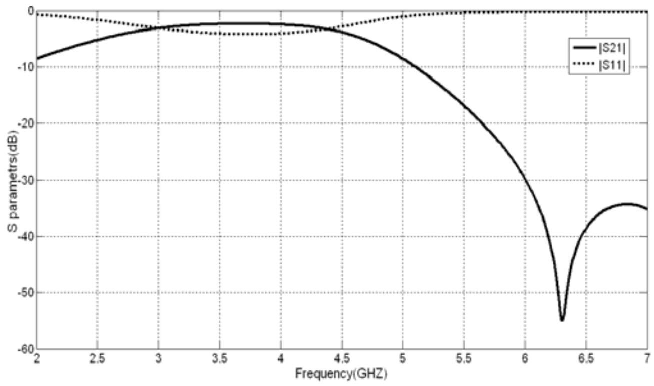

Fig. 5. Frequency response of a stub loaded coupled line.

Base on the above simulation result, we can apply the proposed structure to the parallel coupled microstrip filter for harmonic suppression. So we introduce quarter-wavelenght stubs to suitable position of the coupled section. The detail of the design of the proposed structure is shown in the next section.

III. HARMONIC SUPPRESSION

First to suppress the second harmonic passband of the filter, one set of stubs are placed on the first and fourth coupling section of the previous filter as shown in Fig. 6. In the design process, we should consider the following points:

1) The length of the stubs is a quarter of wavelength at the first harmonic frequency.
2) The best position for the stubs is near the edge of the coupled lines so that it slightly affects the passband characteristics.
3) The structure should be symmetrical.

So we can design the filter according to the structure of Fig. 6. The final dimension of the filter is obtained by optimization process and is demonstrated in Table II, where w_a, l_a, a are the width of stub, length of stub and distance of stub from the beginning line. And some parameter of the conventional filter is changed, slightly trough the optimization.

Fig. 6. The structure of proposed parallel coupled filter with stub loaded.

Fig. 7 shows the simulated results of the proposed structure. In this figure the simulation result of the conventional filter with the same dimension is plotted for comparison. It shows that the second harmonic passband is suppressed more than 30 dB but he passband does not change significantly.

TABLE II: DIMENSION OF THE PROPOSED FILTER WITH STUB (THE DIMENSION ARE IN MILLIMETER).

$l_{1,4}$	$l_{2,3}$	$w_{1,4}$	$w_{2,3}$	$s_{1,4}$	$s_{2,3}$	w_a	l_a	a
16.3	16.7	0.3	0.9	0.2	0.3	0.2	1	1

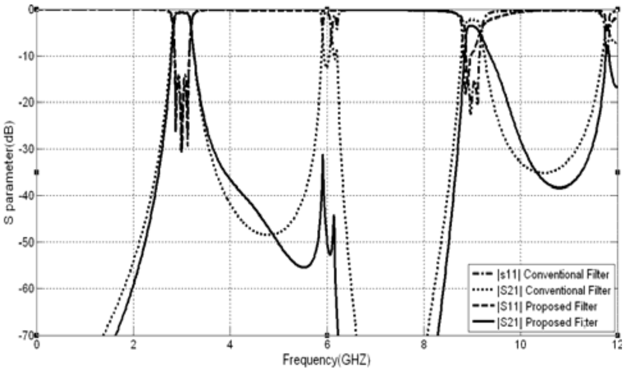

Fig. 7. Comparison between the simulated S-parameter of the proposed and conventional parallel coupled-line filter.

To suppress third harmonics, we should insert two other stubs to the structure. We introduce these stubs to the middle sections of the structure. The length of the stubs is $\lambda_g / 4$ where λ_g is the wavelength at the second harmonic frequency and also we should keep the symmetrical of the structure. The structure of the filter is shown in Fig. 8. The dimension of this structure is as same as the dimension of the structure of Fig. 6 except that $w_b = 0.2mm$, $l_b = 5mm$, $b = 14.7mm$, where w_b and l_b are the width and length of the second stub respectively and b is the distance of the second stub from the beginning of the second coupling section. Fig. 9 shows the simulation results of the proposed filter. We can see that for the tuned double filter, the rejection level for the first and second harmonic passband is vicinity of 30dB.

Fig. 8. The structure of the proposed parallel coupled filter with two set of stubs for multi suppression.

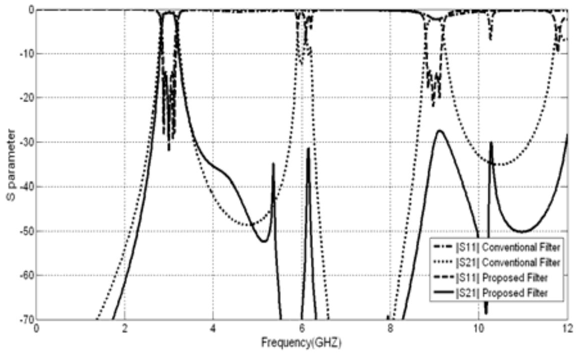

Fig. 9. Comparison between the simulated S-parameter of the proposed and conventional parallel coupled-line filter with two set of stubs for multi suppression spurious

IV. RESULTS AND DISCUSSION

Fig. 10 shows the photograph of the fabricated proposed filter. It has two stubs at first and fourth section for the fist harmonic suppression. For this purpose, we use the dimension of Table II. The comparison between the measurment result of the conventional and proposed filter is illustrated in Fig. 11. We can see that the rejection level of the first harmonic is more than 30 dB while the passband does not change significantly. The measurement results show good agreement with the simulation one.

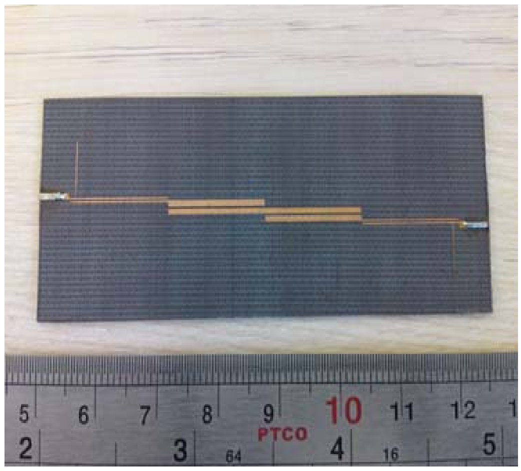

Fig. 10. Photograph of the fabricated filter.

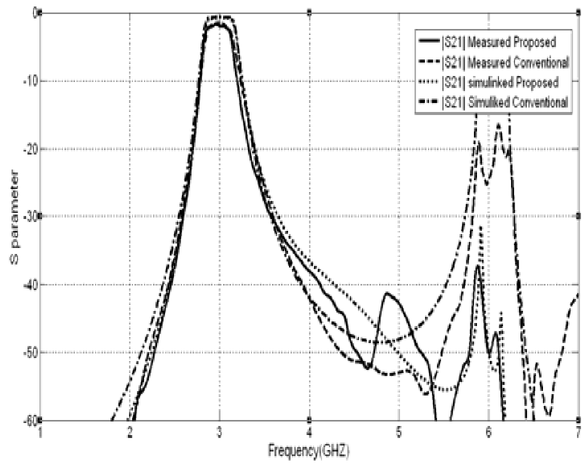

Fig. 11. Simulated and measurement response of the conventional and proposed filter

V. CONCLUSION

A simple technique has been proposed for multispurious suppressing in the parallel coupled bandpass filters. This is achieved by introducing open stubs to the coupled line. By use of this method, the first and second spurious response has been suppressed efficiently while the main passband is almost unchanged. Comparision of the measured and simulated results shows good agreement.

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