A Novel Microstrip Bandpass Filter Design using Asymmetric Parallel Coupled-Line

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***Abstract* — A novel parallel coupled-line bandpass filter with suppression at the 2nd harmonic frequency is presented in this paper. This structure offers a simple design methodology and corresponding implementation. An example of a 900 MHz prototype bandpass filter is used to demonstrate the performance of the new structure. The measured results agree well with the simulation, where, up to 40 dB suppression is recorded at the 2nd spurious response, whilst the matching achieves an interesting level close to 29 dB.**

I. INTRODUCTION

In the past decades, the traditional parallel coupled-line bandpass filter [1], shown in Fig. 1(a), has been extensively studied and widely used in RF front-ends design. But, the performance of this structure suffers from the existence of spurious passbands generated at the multiples of the operating frequency. This intrinsic limitation degrades the stopband rejection behavior and limits its field reliability.

In order to eliminate the above spurious passbands (also referred as harmonics) and to obtain a good out-of-band performance, a recent modification has been introduced in the conventional parallel coupled-line bandpass filter leading to a parallel-coupled wiggly-line architecture [3]. This structure introduces continuous and periodic sinusoidal perturbation along the coupled-line offering wave impedance modulation so as to yield *Bragg* reflection at certain frequencies. Although notable 2nd spurious response suppression is attributed, this is only achievable through complex filter geometry. In addition to this approach, indentation of rectangular-wave contour (square-grooves) has also been recently presented [4-5], although the filter geometry is still a matter of concern.

Introducing λ/4 resonator with open stub in the parallel coupled-line leads to the implementation of transmission zeros that will eliminate filter's harmonics [6-8]. And using correct stub's width and length dimensions, the transmission zero can be placed in the proximity of those harmonics allowing wider stopbands. The major drawback would be an obvious increase of the filter's size.

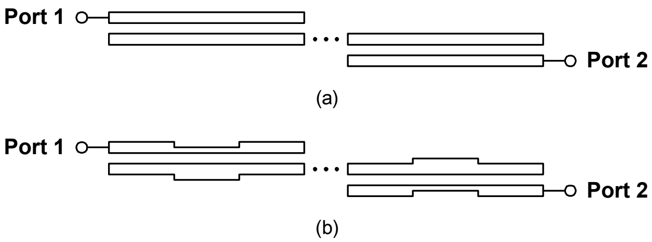

Fig. 1. Parallel coupled-line bandpass filter: (a) Conventional structure. (b) Proposed novel structure using asymmetric coupled transmission lines.

In this paper, a novel parallel coupled-line bandpass filter using asymmetric parallel coupled-line [2] is proposed as depicted in Fig. 1(b). Conventional quasi-TEM microstrip parallel coupled-line bandpass filter has an intrinsic transmission zero located at frequencies higher than the 2nd harmonic. By adopting such type of structure, spurious response suppression is obtained by relocating a transmission zero close to the harmonics whilst preserving the well-defined filter design procedure and layout simplicity. The proposed filter structure is described in Section II where the basic elements of the proposed filter will be analyzed, as well as the effect of those elements on the resonant frequency, 2nd harmonic response and transmission zero. Also, the relationship between the perturbation size and the transmission zero location will be explored. To demonstrate the usefulness and efficiency of the proposed structure for parallel coupled-line filters' harmonics suppression, the simulation and the experimental results of a prototype are presented in Section III. Finally, the conclusions are drawn in Section IV.

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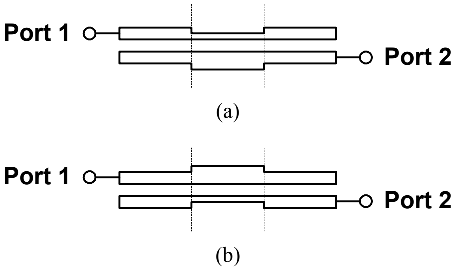

(a)

(b)

Fig. 2. Basic asymmetric parallel coupled-line (a) Type I; (b) Type II.

II. ASYMMETRIC PARALLEL COUPLED-LINE

As illustrated in Fig. 1(b), the proposed filter structure exhibits the same basic pattern of the conventional coupled-line from Fig. 1(a). However, some asymmetry has been added in the newly proposed parallel coupled-line as shown in more detail in Fig.2. Here, the introduced asymmetric lines contribute to the modulation of the characteristic impedance of the coupled-line, thus reallocating the 2nd harmonic and the transmission zero. There are two possible types of lines (Type I and Type II) and three equal length subsections can be considered to implement them, each with 1/3 of the conventional design length, that is, $\lambda_0/12$ (where λ_0 is the guided wavelength), for simplicity. Without loss of generality, in the three sections of type I, only the width of the one in the middle will be perturbed by the width modulation factor M whilst the other two end sections' widths are kept as those from the conventional design. On the other hand, the structure of type II is similar to type I except with an alteration in the direction of the perturbation that will be the opposite. Moreover, both type I or type II can be cascaded allowing the design of higher orders filters. Then, the following 4 cases can be considered for analysis:

Case 1: *Conventional parallel coupled-line.*

Case 2: *Type I or II is used as both input and output.*

Case 3: *Type I is the input whilst type II as the output.*

Case 4: *Type II is the input whilst type I as the output.*

The above 4 cases were simulated as basic examples using the MoM based electromagnetic simulator [9] to compare the features of each case with the conventional parallel coupled-line. Each case was designed at a resonant frequency of 900 MHz with 20% fractional bandwidth, with the simulation results at resonant frequency presented in Fig. 3. Here, it is clearly shown that the center frequency shifts to lower frequency in case 2 and case 4 whilst the center frequency of case 3 is almost unaltered (when compared with case 1). Regarding the 2nd harmonic locations, as presented in Fig. 4, both responses of case 2 and 4 shifts to lower

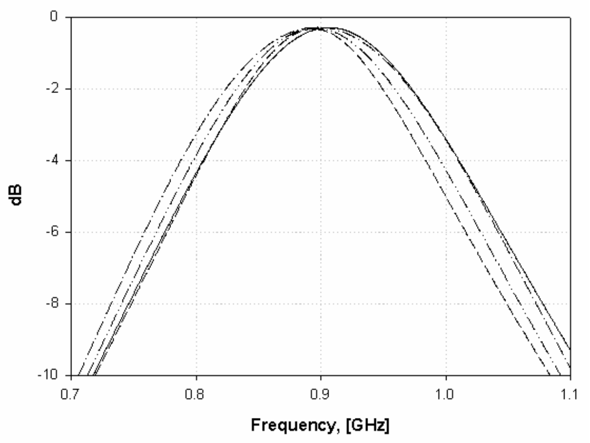

Fig. 3. Resonant frequency locations with M = 50% for conventional parallel coupled-line, case 1 (——), case 2 (— · · —), case 3 (— · —), and case 4 (— — —).

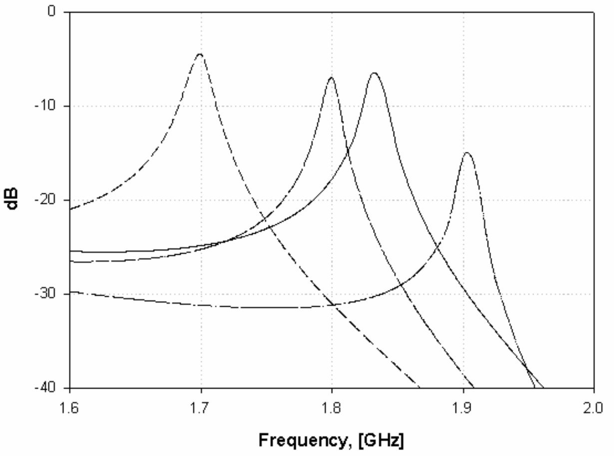

Fig. 4. 2nd hamonic locations with M = 50% for conventional parallel coupled-line, case 1 (——), case 2 (— · · —), case 3 (— · —), and case 4 (— — —).

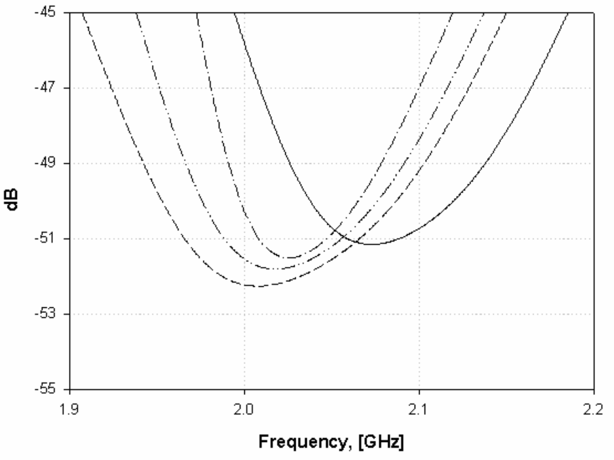

Fig. 5. Transmission zero locations with M = 50% for conventional parallel coupled-line, case 1 (——), case 2 (— · · —), case 3 (— · —), and case 4 (— — —).

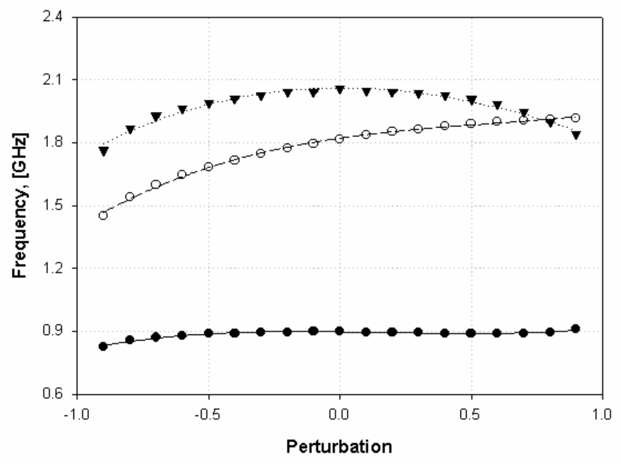

Fig. 6. Variations of f_0 (—●—), 2nd harmonic (— ○ —) and transmission zero (· ▼·) with M for cases 3 (Type I + Type II) and 4 (Type II + Type I).

frequency and only case 3's response shifts to higher frequency. Moreover, it has been also found that for cases 2, 3 & 4, the transmission zero location shifts to lower frequency when compared with case 1**,** as it is evident in Fig. 5.

In order to illustrate clearly the perturbation effect (by variation of *M*) the relationship between *M* and resonant frequency, 2nd harmonic and transmission zero location are summarized in Fig. 6. Positive values of *M* stand for case 3 (Type I + Type II) whereas negative values stand for case 4 (Type II + Type I). As such, it can be concluded that the transmission zero location only relies on the absolute value of *M*, implying that for both cases, the transmission zero location is similar for the same value of *M*. However, the 2nd harmonic shifts to a higher frequency band as the perturbation increases for both cases. In general, the 2nd harmonic is usually located at lower frequency in case 4 when compared with case 3. Also, it is clear that the variation of *M* has almost no influence on the resonant frequency since for any value of *M*, the resonant frequency is still quite close to 900 MHz. Considering the 2nd harmonic and transmission zero locations, it is found that in case 3, when *M* approaches to 76%, the location of the 2nd harmonic and transmission zero have an intersection. Thus, it implies that a design with *M* = 76%, will achieve a higher 2nd harmonic rejection level.

III. SIMULATED AND MEASURED RESULTS

Since an intersection of 2nd harmonic and transmission zero is observed for case 3, thus the behavioral evaluation of a prototype filter of such type would be the main objective of the following design. In order to demonstrate the performance of the proposed structure, a first order maximally flat bandpass filter @ 900 MHz with 20% fractional bandwidth has been implemented (as shown in Fig. 7). The substrate used is RO4003 with a dielectric constant of 3.38 and thickness of 1.524 mm. The corresponding dimensions of the filter are listed in Table 1. On the other hand, the simulation results of a conventional parallel coupled-line and the proposed prototype filter with *M* = 76% are shown in Fig. 8.

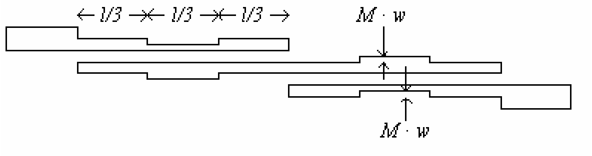

Fig. 7. Proposed Filter Structure (Asymmetric Parallel Coupled-Line).

TABLE 1. FILTER DIMENSIONS IN mm.

l	*s*	*w*	*M*
52.65	0.7	1.0	76%

It is apparent that there is great spurious suppression of 44 dB @ 1.8 GHz, whilst the passband edges are sharpened. Moreover, a transmission zero with –53 dB is recorded @ 1.93 GHz and this transmission zero is crucial for the suppression of the 2nd harmonic. The slight difference in the bandwidth is due to variations of the coupling coefficient.

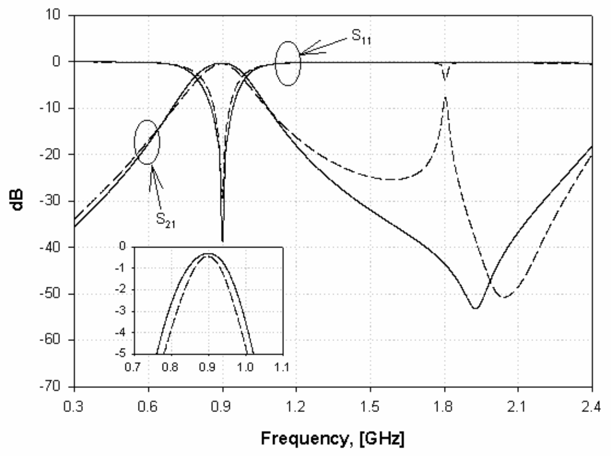

Fig. 8. Simulated S-parameters of conventional parallel coupled-line bandpass filter (— — —) and proposed filter (——).

To test the performance of the proposed filter a prototype was fabricated in the same substrate, as presented in the photo of Fig. 9 (with a size of 126.0 × 12.1 mm^2).

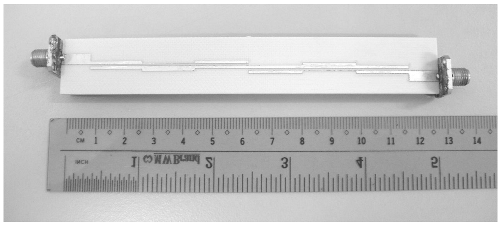

Fig. 9. Prototype filter photo.

The measured S-parameters results reported in Fig. 10, with a 2nd harmonic suppression of 40 dB, constitute a real proof of the superb performance of the proposed filter and confirm the simulation results. The transmission zero is recorded at 1.9 GHz, attenuated by 44 dB, and the measured matching is also considerably good with a value close to 29 dB, thus demonstrating the proposed filter usefulness.

IV. CONCLUSIONS

A novel parallel coupled-line filter using asymmetric coupled transmission lines has been proposed to suppress the spurious passband at the second harmonic. To verify this approach a 900 MHz prototype microstrip filter was design and fabricated. The proposed filter offers 40 dB suppression at the 2nd harmonic and a transmission zero at 1.9 GHz with 44 dB attenuation. The design of the proposed structure follows a simple design methodology and recalculation of the prototype filter parameters was not necessary, thus extending the design flexibility of the conventional parallel coupled-line filter.

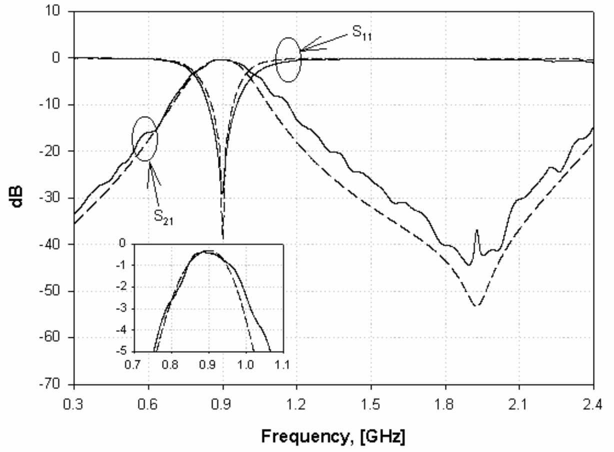

Fig. 10. S-parameters of the proposed filter (- - Simulated; ── Measured).

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