Modified Microstrip Filters Improving The Suppression Performance of Harmonic Signals

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Abstract — **In this paper, a new parallel-coupled-line microstrip BPF(Bandpass Filter) improving the suppression performance of 2nd harmonic signals is described. Using the consecutive patterns in coupled-line, the desired passband performance is improved and harmonic passband signal is diminished. Recalculation of design parameters(space-gap between lines, line widths and lengths) of conventional filters is not required. Because, after using the conventional design methodology for parallel-coupled-line BPF, new filters can be easily realized by inserting periodic patterns in coupled-line. To evaluate the validity of this novel technique, order-3 Butterworth BPF centered at 2.5 GHz with a 10% FBW(Fractional Bandwidth) and order-5 Chebyshev BPF centered at 10 GHz with a 15% FBW were used. When five and three square grooves are used, over 30 dB suppression at 2nd harmonic is achieved in simulation and experiment.**

I. INTRODUCTION

The parallel-coupled-line theory can also be used to construct many types of filter. Fabrication of multisection bandpass or bandstop coupled-line filters is particularly easy to make in microstrip form, for bandwidths less than about 20%. Required design parameters of BPF can be easily derived for Butterworth and Chebyshev prototypes described in many literatures[1]-[3].

Though this type of filter is general and easy to implement, it suffers from the presence of spurious passbands at harmonics of the design frequency. For example, if coupled-line filter is used at the next stage of frequency converter, harmonic signal originated from frequency converter still exist. Consequently, this phenomena result in the degradation of system performance. To lower the level of these harmonics, the lowpass filter is generally added to the bandpass filter. But this solution increases filter layout area and introduces additional insertion losses. Hence it is necessary to obtain a design technology that can reduce size and reject a harmonic signal.

Uniplanar compact photonic-bandgap(UC-PBG) structure with periodic patterns etched in the ground plane has been proposed to reject a harmonic and to reduce the total filter size, but the physical and electrical parameters of coupled lines must be recalculated in this structure[4]. Other PBG structures with sinusoidal patterns or triangular patterns in the ground plane using Bragg condition are proposed[5]-[6]. The 45 dB and above of harmonic rejection for triangular wave and 50 dB and above of harmonic rejection for sine wave were achieved, but these have the increased size problem as well as those of UC-PBG. Another method, DGS having a defected pattern of slot in the ground plane like PBG, is recently investigated to introduce a lowpass filter characteristics by increasing capacitance and inductance of transmission lines on the defected ground[7].

To overcome and improve the disadvantages caused by longitudinal and lateral displacement of each patterns of PBG and DGS on both sides of the substrates, “wiggly-line filter” using a continuous perturbation of the coupled-line width has been suggested[8]. In [8], the wave impedance is modulated so that the harmonic passband of the filter might be rejected while the desired passband response remains virtually unaltered. But the etching of sine wave on transmission line is not easy and the S_{21} near at harmonic frequency still remains.

In this paper, a modified structure is proposed by applying the general ideas of above-mentioned and Bragg condition to microstrip line to improve harmonic suppression characteristics, and this paper describes the design method of two filters operating at 2.5 GHz and 10 GHz, and the process of inserting square grooves.

II. FILTER DESIGN

A. Parallel-coupled-line Filter Design

To test the performance of proposed novel filter, we have designed order-3 bandpass filter centered at f_c = 2.5 GHz with 10 % fractional bandwidth. The employed substrate has relative dielectric constant, ε_r = 10.2 and thickness, h = 1.27 mm of Rogers RT/6010.

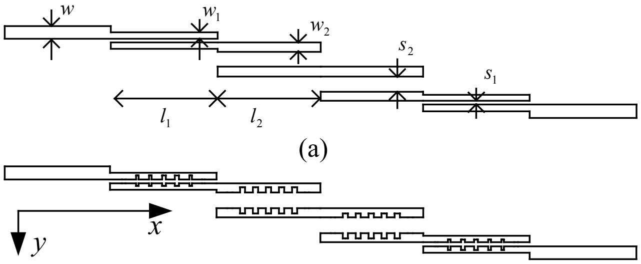
The equation to obtain the layout parameters of conventional parallel-coupled-line microstrip filter is very well known and can be found in classical microwave books. The same specifications used for designing “wiggly line filter”[8] are applied to the design of rectangular-grooved filter.

TABLE I

PHYSICAL PARAMETERS FOR THE ORDER-3 BUTTERWORTH BPF CENTERED AT 2.5 GHZ WITH A 10% FBW

n	$Z_{0e}(\Omega)$	$Z_{0o}(\Omega)$	w_n	s_n	l_n
1	77.66	38.0377	0.75	0.42	11.98
2	56.17	45.0622	1.09	1.70	11.54

In Table I, section number n, even and odd mode characteristic impedances $Z_{0e}(\Omega)$, $Z_{0o}(\Omega)$ and the strip widths, $w = 1.5$ mm of the input and output ports($Z_0 = 50$ Ω) are described.



(a)

(b)

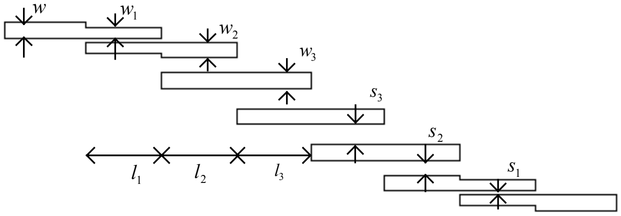
Fig. 1. With 2.5 GHz center frequency (a) Conventional parallel-coupled-line BPF: conductor strip widths w_n, length of coupled-line sections l_n, and separation between the coupled lines of the section s_n. (b) Modified filter obtained by applying five square grooves at (a).

To prove the applicability of the modified filter regardless of filter type or frequency, we have designed order-5 Chebyshev bandpass filters centered at f_c = 10 GHz with FBW = 15%. The employed substrate has relative dielectric constant, ε_r = 10.2 and thickness, h = 0.635 mm.

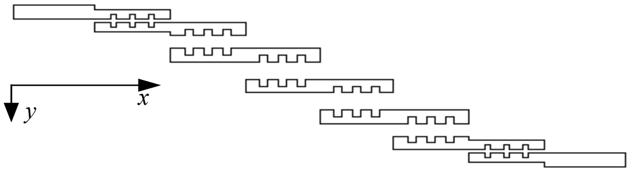
TABLE II

PHYSICAL PARAMETERS FOR THE ORDER-5 CHEBYSHEV BPF CENTERED AT 10 GHZ WITH A 15% FBW

n	$Z_{0e}(\Omega)$	$Z_{0o}(\Omega)$	w_n	s_n	l_n
1	82.9367	37.6092	0.385	0.161	2.852
2	61.1600	42.3705	0.575	0.540	2.772
3	58.1839	43.8661	0.595	0.730	2.756



(a)



(b)

Fig. 2. With 10 GHz center frequency, (a) Conventional parallel-coupled-line BPF, (b) Modified filter obtained by applying three square grooves at (a).

In Table II, the used strip widths of the input and output ports for the order-5 chebyshev filter are all 0.59 mm.

B. Parallel-coupled-line Filter Design with Grooves

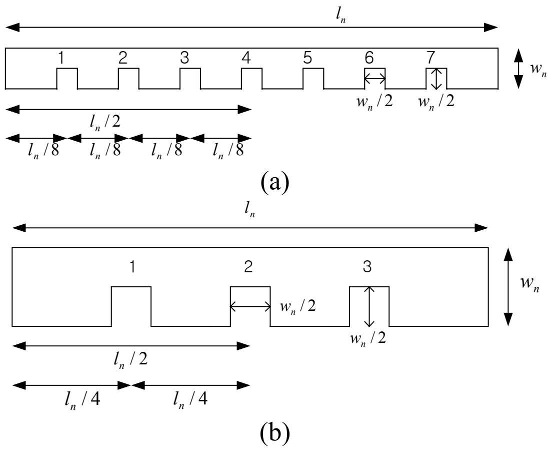
In the designed filters, the periodic square grooves are placed at the both sides of coupled-line symmetrically, where l_n is $\lambda_g/4$ length of design frequency and λ_g is guided wavelength.

In Fig. 1(b) and 2(b), k_x is the wavenumber of TEM mode propagating at $+x$ axis. The condition for Bragg reflection is given as in (1):

$$2\, k_x\, D = 2\pi n \quad (n = 1, 2, \dots, \text{an integer}) \tag{1}$$

where D is the period of the perturbation and is equally said to be beat wavelength[8]. For the design frequency f_c, the condition for generating Bragg reflection at harmonic frequency of $2\, f_c$ is written as in (2). D can be obtained from (2) as $\lambda_{gc}/4$, where λ_{gc} is the wavelength of design frequency.

$$8\pi D / \lambda_{gc} = 2\pi \quad (\text{if } n = 1) \tag{2}$$



(a)

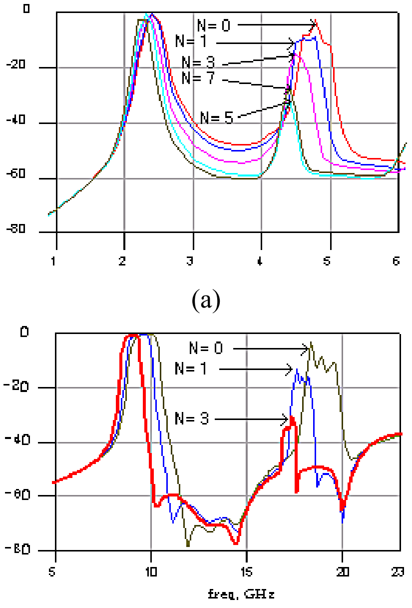
(b)

Fig. 3. (a) Modified $\lambda_g/4$ line in 2.5 GHz filter (b) Modified $\lambda_g/4$ line in 10 GHz filter.

In Fig. 3(a) and (b), the general shapes of $\lambda_g/4$ line with square grooves are shown. Each side of square grooves is a half of each coupled-line width, w_n and the center of each square is located at 1/8 and 1/4 of l_n. The number of the square grooves is one(groove position : 4), three(2, 4, 6), five(2, 3, 4, 5, 6), or seven(1, 2, 3, 4, 5, 6, 7) in 2.5 GHz filter and one(2), three(1, 2, 3) in 10 GHz filter from Fig. 3(a).

II. SIMULATION AND MEASUREMENT RESULTS

The calculated results were obtained by using Ensemble 4.0 of Ansoft and MWS 3.2 of CST based on MoM and FDTD algorithm, respectively. From the simulation results of the 2.5 GHz filters with grooves in Fig. 4(a), we can see that the conventional coupled-line filter generates high signal level at 2nd harmonic and the more the number of groove increases, the more 2nd harmonic signal level and bandwidth decrease, and the center frequencies move to the lower. These phenomena are due to an increased path length of wave caused by inserting the periodic square grooves. The harmonic suppression characteristics of seven-grooved filter approaches to the worst because of the strong interferences caused by the small interval between the grooves deviating the range of $l_n/4 \sim l_n/8$.



(a)

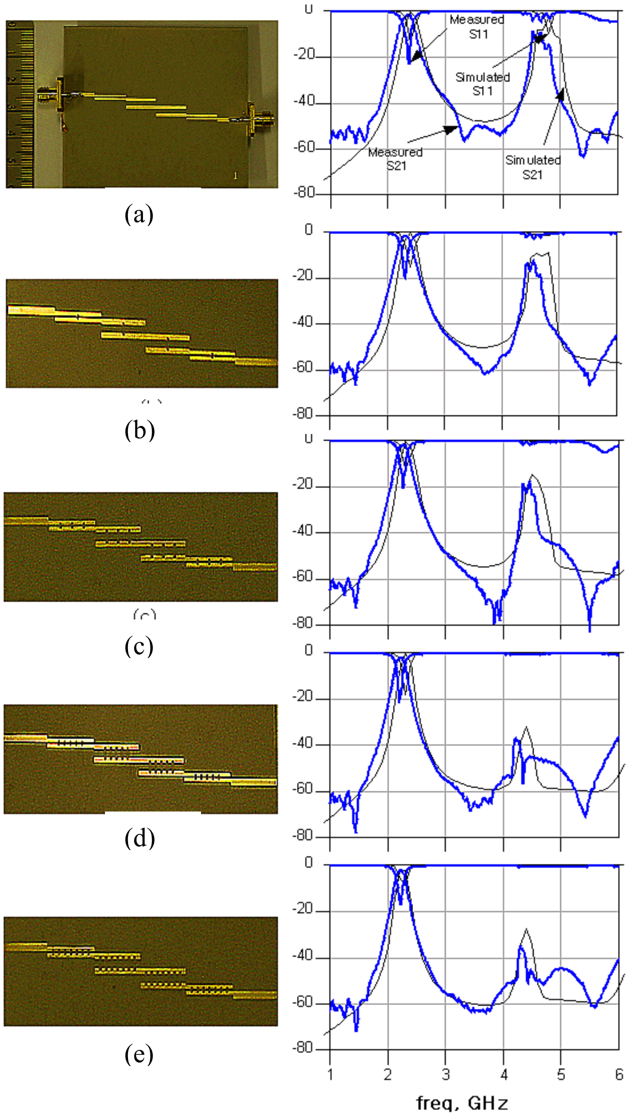
(b)

Fig. 4. Simulated (a) S_{21} for filter centered at 2.5 GHz with grooves (b) S_{21} for filter centered at 10 GHz with grooves.

Fig. 4(b) shows the simulation results of 10 GHz filters. The same phenomena as in the 2.5 GHz filters are obtained. When the number of grooves is 3, about 30 dB rejection effect is obtained. The simulation results show that these square grooves can be applied regardless of filter type(Butterworth or Chebyshev) or frequency

To verify simulation results, 2.5 GHz filters were implemented and measured. The relative dielectric constant and thickness of the used substrate are $\varepsilon_r = 10.2$ and h = 1.27mm of Rogers RT/6010, respectively, and the measurements have been realized with a Agilent E8357A PNA Series Network Analyzer.

Fig. 5 shows good agreements between simulations and experimental results. The more the number of groove increases from 0 to 5, the more 2nd harmonic signal decreases. The rejection level reaches the maximum –35 dB and below when the number of the grooves is 5. And when grooves number is 7, harmonic signal level increases a little bit. The cut-off rate of the proposed filters for stopband was improved about 10 dB by comparing with that of the conventional coupled-line filters.



(a)

(b)

(c)

(d)

(e)

Fig. 5. Photographs of filter centered at 2.5 GHz with groove numbers of (a) 0, (b) 1, (c) 3, (d) 5, (e) 7, and simulated results(thin line) and measured results(thick line)

II. CONCLUSIONS

This paper suggested a novel method to improve harmonic suppression characteristics by applying the square grooves to meet Bragg condition at conventional parallel-coupled microstrip bandpass filter.

As a result, 30 dB and above of harmonic rejection and a good cut-off characteristics at the design frequencies were obtained. In addition, the advantages of saving time and low cost were obtained without recalculating physical design parameters of conventional filter.

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