Resonator Bandpass Filter Using the Parallel Coupled Wiggly Line for Supurious Suppression

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ABSTRACT — **This paper describes the resonator bandpass filter design using the non-uniform parallel coupled "wiggly-line" technique. The proposed resonator is consisted of three sections quarter wavelength coupler and each of sections has perturbation and Z_0 connected in the end of each ports. This resonator can reduce the spurious response at $2f_0$ and $3f_0$ by its structure. The directivity enhanced parallel-coupler should be employed to solve this problem. The experimental results and designs of all type are 0.9 GHz to implement bandpass filters. There were evidently shown the second and third spurious response suppression improvement. Both the theoretical and experimental performance is presented.**

Index Terms **— Parallel coupled line, non-uniform coupled line, bandpass filter, spurious suppression, wiggly-line.**

I. INTRODUCTION

A parallel-coupled (edge-coupled) microstrip bandpass and bandstop filters which are widely used a half wave length line resonator. The microstrip filter parameters can be derived by using both Chebyshev and Butterworth prototypes [1]. This type of filter suffers from spurious bandpass at the harmonic frequency. The even-mode and the odd-mode phase velocities for a coupled pair of microstrip lines are unequal [2]. Because the microstrip is a non-homogeneous medium (it is consisted of air above and dielectric below medium) [3]. In the past, the capacitive and inductive compensating techniques were proposed to improve the symmetry of bandpass, spurious free response of the microstrip coupled lines based bandpass filters [4], and other methods have been also proposed in the literature to eliminate this first spurious passband [5], [6]. To suppress or reject this spurious response, in this paper, we introduce the resonator bandpass filter design using parallel coupled "wiggly-line". This technique is proposed to more suppress the spurious response. This is achieved by designing the parallel coupled (edge coupled) line by Chebyshev prototypes and step of design of the parallel coupled "wiggly-line. Although this structure is very good to suppress the spurious response but it is not miniature circuit for using the limited area in microwave equipment. In section II, we present a comprehensive circuit theory, the propose technique of the resonator bandpass filter is based on parallel coupled "wiggly–line". This structure of resonator can suppress the second and third spurious response by itself. The step design and all results of the proposed parallel coupled "wiggly-line" bandpass filters are described in section III. The finally of this paper is a conclusion in section IV.

II. THEORY AND DESIGN

The resonator bandpass filter based on parallel coupled "wiggly-line" is composed of three sections of parallel coupled line with asymmetry shape of perturbation. Input and output ports are tapped in the end of the coupled line. This configuration of input and output port feeding causes the magnitude of input/output impedances pulled raise up. Therefore, step impedance transmission lines are employed both in input and output port to step down the port's impedance close to the magnitude of characteristic impedance Z_0. Parallel-coupled (or edge-coupled) bandpass filters, for this method, maximum coupling are obtained between physically parallel microstrip when the length of the coupled region is $\lambda_g/4$ therefore the microstrip circuit must have the general layout shown in Fig. 1(a), where l_1, l_2, $l_3 \approx \lambda_g/4$.

The parallel coupled "wiggly line" microstrip bandpass filters with spurious suppression are designed from Chebyshev bandpass filters with centered at f_0 =0.9 GHz. The substrate employed has relative dielectric constant ε_r = 6.0 and strictness h = 1.52 mm. The first stage in the design process of the "wiggly line" filter is calculated from the conventional parallel coupled microstrip geometry. The schematic of the parallel coupled line is depicted in Fig. 1(a), while the schematic of the proposed filters are depicted in Fig. 1(b) and 1(c). The outlining a design steps are following below

For the first coupling structure
Ripple = 0.1 dB, g_0 =1, g_1 =0.843, g_2 = 0.662, g_3= 1.3554, δ = the fractional bandwidth

$$J_{0,}Z_0 = \sqrt{\frac{\pi\delta}{2g_0 g_1}} \qquad (1)$$

$$\delta = \frac{f_2 - f_1}{f_0} \qquad (2)$$

For the intermediate coupling structures, $\omega'_c = 1$

$$J_{j,j+1}Z_0\big|_{j=1to(n-1)} = \frac{\pi\delta}{2\omega'_c\sqrt{g_j g_{j+1}}} \qquad (3)$$

For the final coupling structure

$$J_{n,n+1}Z_0 = \sqrt{\frac{\pi\delta}{2g_n g_{n+1}}} \qquad (4)$$

When n=2 (order), g_0 =1, g_1 =0.843, g_2=0.622, g_3 =1.3554

$$(Z_{0e})_{j,j+1} = Z_0(1 + aZ_0 + a^2Z_0^2) \qquad (5)$$

$$(Z_{0o})_{j,j+1} = Z_0(1 - aZ_0 + a^2Z_0^2) \qquad (6)$$

$a = J_{j,j+1}$

Z_{0e} = odd mode coupled line impedance

Z_{0o} = even mode coupled line impedance

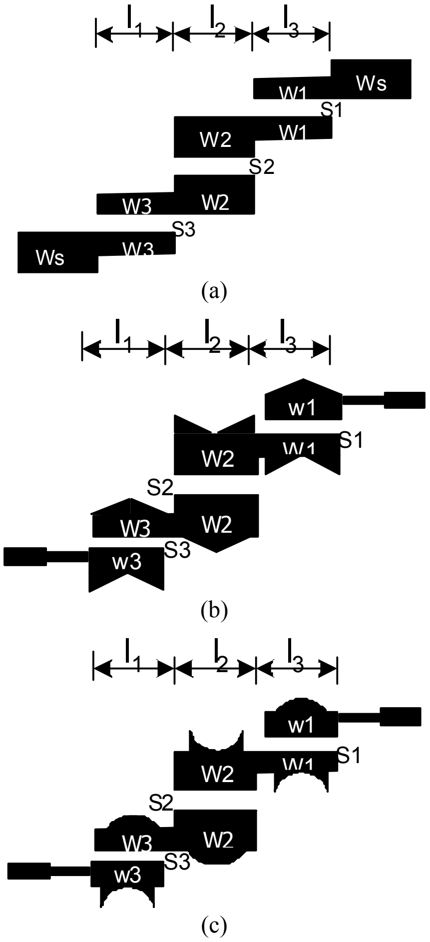

Figure. 1 (a) Parallel coupled line and (b) Resonator bandpass filter using the parallel coupled "wiggly-line" line type I and (c) type II

TABLE I
THE ELECTRICAL PARAMETER FOR THE PARALLEL COUPLED LINE SECOND-ORDER BANDPASS FILTER.

j	$J_{j,j+1}Z_0$	$(Z_{0e})_{j,j+1}$	$(Z_{0o})_{j,j+1}$
0	0.43175	80.9079	37.7329
1	0.21701	63.2051	41.5041
2	0.43173	80.9060	37.7330

TABLE II
THE PHYSICAL PARAMETERS FOR THE SECOND-ORDER PARAMETERS CHEBYSHEV BANDPASS FILTER CENTERED AT 0.9 GHZ WITH 10% FRACTIONAL BANDWIDTH

j	W (mm)	S (mm)	L (mm)
0	1.8630	0.425	46.894
1	2.6011	0.8497	45.875
2	1.9236	0.2918	47.045

Table I shows the electrical parameter for the parallel coupled line second-order bandpass filter. While the table II shows the physical parameters chebyshev bandpass filter centered at 0.9 GHz with 10% fractional bandwidth. The coupler which have Z_0 = 50Ω, C = - 8.2 dB, Z_{0e}, Z_{0o}, $\theta = \pi/2$, 1 = $\lambda_g/4$ We get three of microstrip line dimensions are finally obtained as follows (substrate permittivity ε_r = 0.6) The second stage in the design process is calculated the period of the sinusoidal perturbation to adjust it to suppress the spurious response at $2f_0$, for f_0 is the design frequency. This employed rejection correspond to backward coupling of the kind of Bragg reflection in the same, but counter propagation mode is the coherence relationship reduce to

$$\Delta\beta = 2\beta_1 = 2.\frac{4\pi}{\lambda_g} = \frac{2\pi}{\lambda_B} \qquad (7)$$

where λ_g is the guide wavelength at the design frequency, $\lambda_B = \frac{\lambda_g}{4}$ is the beat wavelength, β_1 is the mode phase constant at the frequency to be rejected and $\Delta\beta$ is the difference between the unperturbed phase constants of two interaction modes. Each coupled-line section of the filter has its own mean phase constant value and its own guided wavelength at the design frequency. In every coupled line section have the same electrical length of 90 degree at the design frequency. The last stage in the design process consists on the introduction of the perturbation in the conventional filter previously designed. This perturbation is introduced in an asymmetrical way. The constructor strip-width variation $w_i(z)$ in the *i* th coupled-line section can be expressed as follows:

$$w_i(z) = w_i\left(1 + \frac{1}{2}\frac{M_i\%}{100}\cos\left(\frac{2\pi z}{\lambda_{B,i}} + \phi_i\right)\right) \qquad (8)$$

ϕ_i are theirs initial phases (0 and 180 degree), w_i is the constant width calculated for the conventional filter, $\lambda_{B,i}$ is the beat wavelength and M_i is the strip-width modulation parameter expressed in percentage.

III. SIMULATED AND MEASURED RESULTS

The simulated and the experimental results were presented for the conventional parallel coupled-line microstrip filter and two types of parallel coupled "wiggly-line" prototypes with perturbations M = 37.5 %. The prototype circuits were designed and fabricated on RF60 microwave substrate. The three parallel coupled have the same coupling factor synthesized from -8.2 dB. The prototype with first coupled lines have factor electrical parameters Z_{0e} = 80.9079 Ω and Z_{0o} = 37.7329 Ω. The second coupled lines have a factor electrical parameters Z_{0e} = 63.2051 Ω and Z_{0o} = 41.5041 Ω.The last coupled was the same as a factor electrical parameter approximately the first coupled. The EM simulated results of the two types of bandpass filter based on the periodically non-uniform coupled line uncompensated were shown in Fig. 2. The proposed bandpass filter's magnitudes type I of S_{21} and S_{11} around f_0 are about -0.43 dB and less than -25.256 dB, while the suppression performances at $2f_0$, and $3f_0$ compare with the bandpass filter are approximately 44.1 dB, and 37.613 dB, respectively. The proposed bandpass filter's magnitudes type II of S_{21} and S_{11} around f_0 were about -0.947 dB and less than -20.705 dB, while the suppression performances at $2f_0$, and $3f_0$ compare with the bandpass filter were approximately 36.10 dB, and 43.254 dB, respectively.

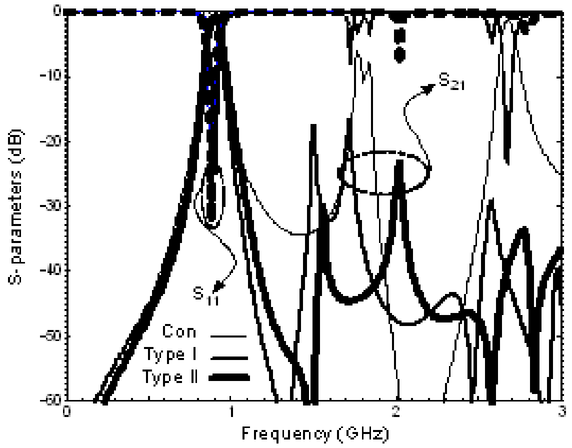

Figure.2 The EM simulated results of conventional parallel coupled line, parallel coupled "wiggly-line" type I and type II.

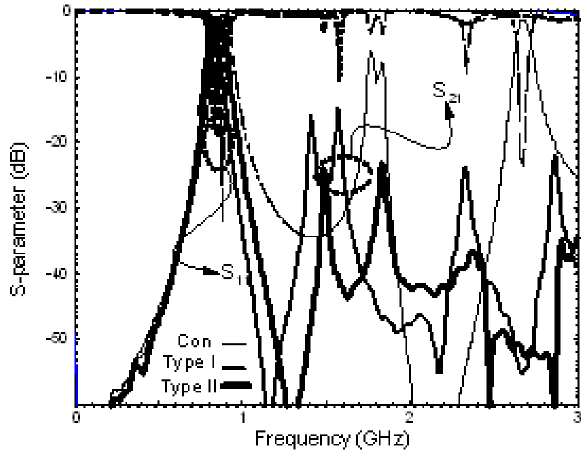

Figure.3 The measured simulated results of conventional parallel coupled line, parallel coupled "wiggly-line" type I and type II.

The measured results of the proposed microstrip coupled-feed filter were shown in Fig. 3. The magnitudes type I of S_{21} and S_{11} around f_0 are about -0.65 dB and -20.16 dB, while the suppression performances at $2f_0$, and $3f_0$ are approximately 42.5 dB, and 54.2 dB, respectively. The magnitudes type II of S_{21} and S_{11} around f_0 were about -0.97 dB and -18.6 dB, while the suppression performances at $2f_0$, and $3f_0$ are approximately 36.7 dB, and 48.6 dB, respectively. The photograph of the print circuit board of the resonator bandpass filter type I and type II based on parallel coupled "wiggly-line" were shown in Fig. 4 and Fig. 5, respectively.

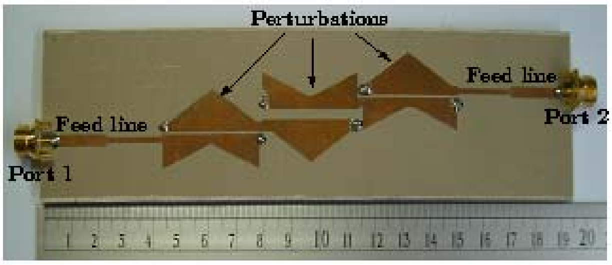

Figure.4 Photographs of parallel coupled "wiggly-line" type I

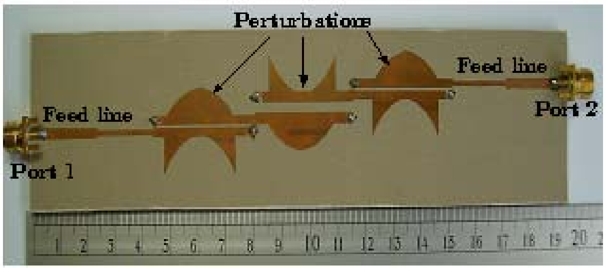

Figure.5_Photographs of parallel coupled "wiggly-line" type II

IV. CONCLUSION

In this paper, the simple design procedures for the resonator bandpass filters based on the parallel coupled "wiggly-line" type I and type II were presented. These resonators give more efficiency of performance to reduce spurious response $2f_0$ and shift $3f_0$ to higher frequency by their structures. The closed form design equations of parallel coupled lines were suitable to use in many wireless and microwave applications. This proposed bandpass filter can be used in many wireless and microwave systems.

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