



Application of Perturbed Linear Resonators

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Abstract- This paper presents the application of perturbed linear resonator (PLR) in the design of a band pass filter with extended stop band performance. Perturbed linear resonator was analyzed using piecewise linear transmission line model. An experimental filter having 35% bandwidth has been designed at a center frequency (f_0) of 2.4GHz. Experimental results showed that the first spurious frequency has been extended to $4.8f_0$, which is 1.28 times compared to the conventional two-section stepped impedance resonator (SIR).

Index Terms- Filter, PLR, Resonator, Spurious

I. INTRODUCTION

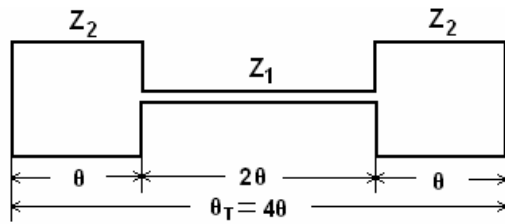
Filters play an important role in the design of wireless communication systems and the rapidly growing spectrum requirements impose stringent requirements on harmonic suppressions. Although conventional parallel-coupled line filters are widely used, they suffer from immediate spurious resonance at $2f_0$ which leads to degraded rejection characteristics. Various techniques have been reported in the literature to suppress the spurious response [2-11]. In [2,3], impedance ratio of the stepped impedance resonator is varied to relocate the second pass band, whereas [4] uses open circuit stubs to attenuate the spurious response. In [5], modulation of wave impedance has been used to reject the harmonic pass band. Suppression of harmonics using the technique of phase velocity equalization has been reported in [6-8]. Stepped Impedance Resonator with three impedance sections is used in [9] to suppress the spurious frequencies. M.C. Velázquez *et. al* [10], reported spurious suppression in microstripline filters

using floating grounds. Using periodical non-uniform microstrip coupled lines, spurious rejection has been achieved in [11].

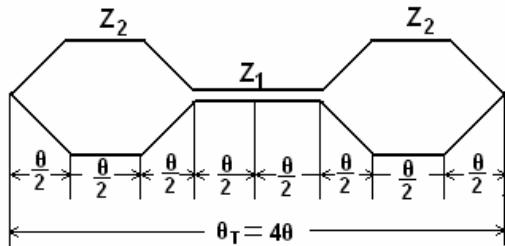
This paper reports the technique of using perturbed linear resonators to design spurious free filters. Section II gives the properties of perturbed linear resonator. Design of the filter based on these resonators along with the measured results is presented in section III. Section IV concludes this paper.

II. ANALYSIS OF PLR

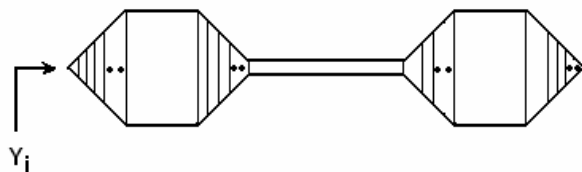
Conventional two section SIR (Fig. 1a) was symmetrically perturbed at the ends as shown in Fig. 1b. All the sections in either half of the resonator (tapered sections and constant impedance sections) have an equal length of ' $\theta/2$ '. For the purpose of analysis, each tapered portion of the PLR has been divided into a sufficiently large number of sections (section length is approximately $0.0017\lambda_g$) as shown in Fig. 1c. Resonant properties of a resonator can be studied as discussed in [2,3]. The admittance ' Y_i ' (looking into the open end) can be evaluated using the principle of cascaded transmission lines. Fig.2 shows the susceptance curves (imaginary part of Y_i) of typical conventional SIR and the PLR for the parameters listed in Table 1. Electrical Lengths of both the resonators were chosen so as to have the same fundamental resonance (f_0). Resonant frequencies of the PLR and SIR as read from Fig.2 are compared in Table 2. Results showed that the PLR relocates the first spurious frequency far away compared to the two-section SIR.



(a)



(b)



(c)

Fig.1. a) Two section SIR
b) Perturbed Linear Resonator
c) Modeling of PLR

Table 1: Electrical Parameters of Resonators

Parameters	Values
Resonant frequency (f_0)	2.4GHz
Z_1	178Ω
Z_2	35Ω
Total electrical Length ' θ_T ' of two section SIR	95.65°
Total electrical Length ' θ_T ' of PLR	114°

Table 2: Properties of Resonators

Properties	Two section SIR	PLR
Fundamental frequency (f_0) (GHz)	2.4	2.4
First spurious frequency (f_{s1}/f_0)	3.76	4.16
Second spurious frequency (f_{s2}/f_0)	6.54	5.47

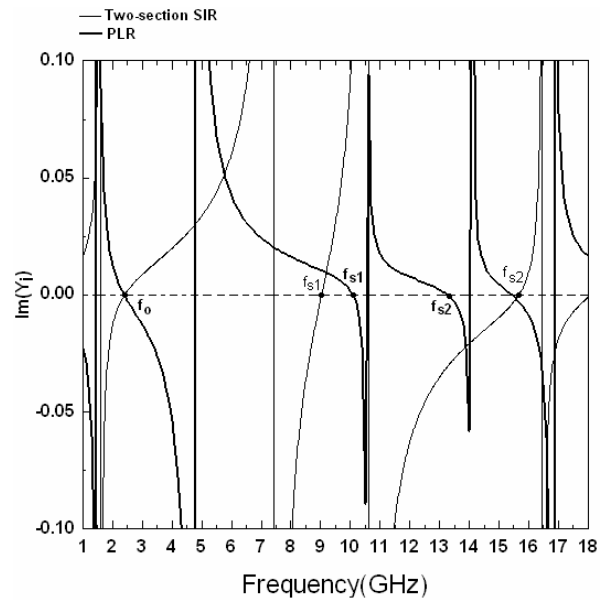


Fig.2. Susceptance curves of SIR and PLR

III. APPLICATION OF PLR

A filter with the following specifications has been considered for the present design.

Center frequency f_0 : 2.4GHz

3dB Bandwidth: 35%

Ripple: 0.1dB

Order: 3

Following electrical parameters have been chosen for the design of SIR and PLR filters.

SIR: $Z_1=178\Omega$, $Z_2=35\Omega$ and $\theta=23.9125^\circ$

($\theta_T=95.65^\circ$)

PLR: $Z_1=178\Omega$, $Z_2=35\Omega$ and $\theta=28.5^\circ$ ($\theta_T=114^\circ$).

Coupling coefficients corresponding to the desired specifications can be calculated from [1] and are found to be $k_{01}=k_{34}=0.52$, $k_{12}=k_{23}=0.34$. Layout of the PLR based filter shown in Fig. 3 has been realized in suspended substrate stripline (SSS) medium. Resonators printed on the top and bottom layers of the PCB give the required tight coupling. The widths and lengths of resonators are $w_1=5.2mm$, $w_2=0.2mm$ and $L_T=4\theta=31.56mm$ respectively. Resonator spacings obtained using EM simulator, (HFSS from Ansoft [12]) have been given in Table 3.

Table 3: Filter Parameters

Spacings	Values (mm)
$S_{01}=S_{34}$	-3.0
$S_{12}=S_{23}$	-2.0

Simulated results of the filters have been shown in Fig. 4. Simulations show that the PLR based filter has the first spurious frequency at $4.16f_0$, whereas the SIR has the first spurious frequency at $3.76f_0$. Further simulations showed that the resonators arranged as shown in Fig. 5 widens the stop band by relocating the first spurious to $4.8f_0$. Fig. 6 compares the experimental results of the modified PLR based filter against the simulation results. Measured results confirm the simulations. Table 4 compares the performance of PLR and SIR filters.

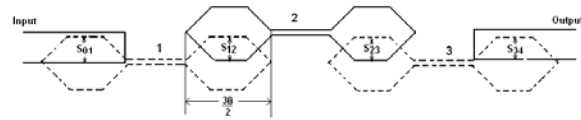


Fig. 5. Layout of modified PLR filter

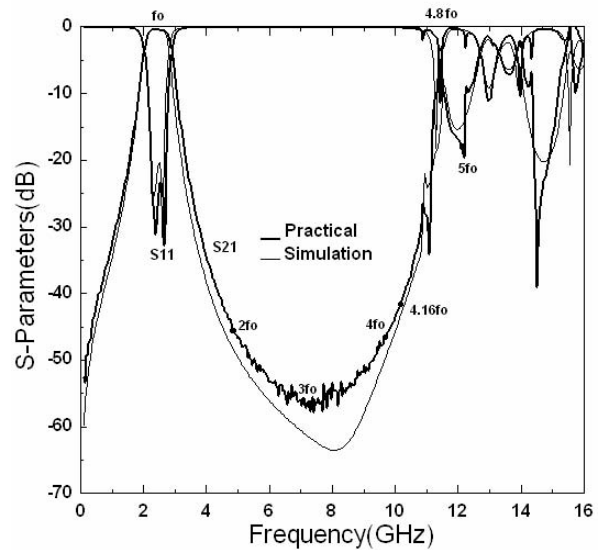
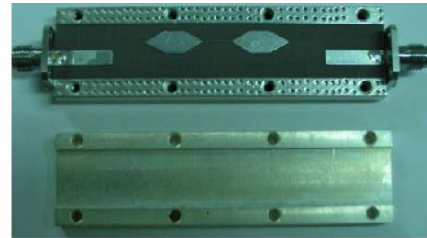


Fig.6. Photograph and results of PLR filter

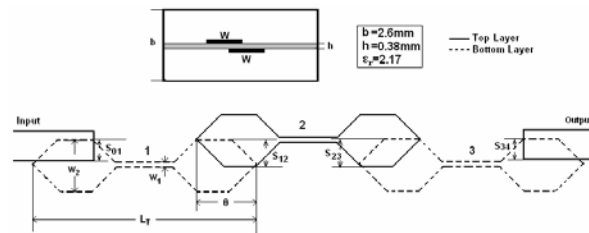


Fig. 3. Layout of PLR filter

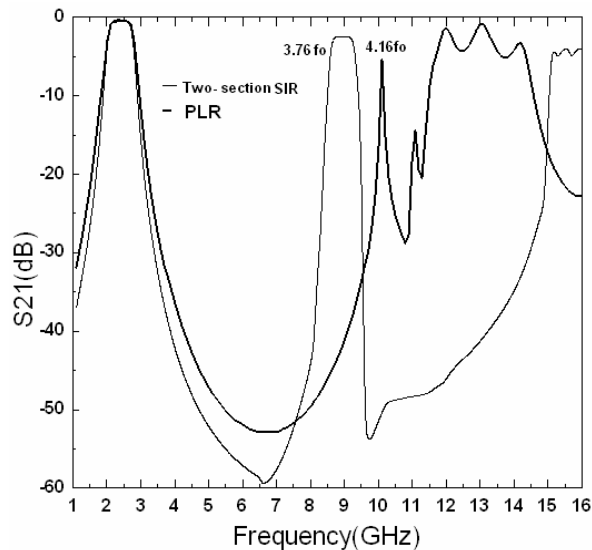


Fig.4. Comparison of SIR and PLR filter

Table 4: Comparison of PLR with SIR filter

Parameters	Two section SIR (Fig. 4)	PLR (Fig. 6)
Fundamental frequency (f_0) (GHz)	2.4	2.4
First spurious frequency (f_{s1}/f_0)	3.76	4.8
Second spurious frequency (f_{s2}/f_0)	6.54	5.62

IV. CONCLUSIONS

Properties of the perturbed linear resonator useful for the design of spurious free filters are presented in this paper. Based on these resonators, a filter has been designed and realized. Measured results showed that the PLR



filter relocates spurious frequency far away compared to SIR and thus widens the stop band.

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