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Procedia Engineering 32 (2012) 550 – 555

Procedia Engineering

www.elsevier.com/locate/procedia

I-SEEC2011

Design Elliptic Lowpass Filter with Inductively Compensated Parallel-Coupled Lines

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Elsevier use only: Received 30 September 2011; Revised 10 November 2011; Accepted 25 November 2011.

Abstract

This paper presents a simple technique to design an ellicptic transfer fuction microstrip lowpass filter based on a section of doubly inductive compensated parallel-coupled lines. The proposed lowpass filter has the suppression performance to suppress the signal transmission in transition and stopband better than the filter based on the conventional coupled lines. The proposed design procedures are convenient with the closed form design equation. To demonstrate the techniques performance, simulated and measured results at 0.9 GHz cut off frequency LPF with uncompensated and the compensated structures are compared. The measured results obtained from the proposed LPF exhibit 0.2 dB insertions, less than 20 dB return loss and more suppression performance than 35 dB at 1.8 GHz.

Keywords: Elliptic transfer function; Microstrip lowpass filter; Parallel-coupled Line and Inductive compensation

1. Introduction

An effective and simple technique to design a compact microstrip low pass filter has been proposed in this paper. The proposed method is highly effective for L-band applications. In general, low pass filters are required to suppress harmonics and unwanted frequencies components in communication systems to increase the system's signal to noise ratio. The most important features of a desirable low-pass filter, which highly demanded are wide rejection bandwidth, sharp cut-off frequency response, wide-band band-pass and low insertion loss [1]. Usually, lowpass filter circuits are designs with high impedance transmission line cascade by low impedance transmission line as a ladder type transmission line or multi section microstrip couple lines [2]. Using Opened and shorted stub transmission line at the quarter

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doi:10.1016/j.proeng.2012.01.1307

wavelength cause an undesirable increase in topology area [3]. Increase of stop band suppression responses by using higher order or sections has a higher insertion loss and circuit size [4].

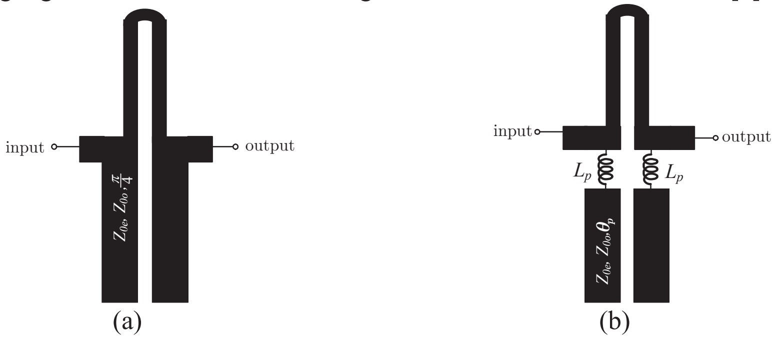

Fig. 1. Schematics of the proposed low pass filter with (a) conventional and (b) inductively compensated parallel coupled lines

Recently, elliptic transfer function low pass filter has been already designed and introduced [5]. It provides a wide band pass-band, but a narrow stop-band and compact size. Several studies have tried to achieve the feature of the wide rejection bandwidth of low pass filters in wideband communication systems [5-6]. A compact elliptic-function low pass filter, which is implemented on microstrip parallel-coupled lines has been proposed. This low pass filter is employed a meander line to provides a wide rejection band, compact size but wide transition band and more complex design equations [7].

In this paper, a similar mentioned elliptic low pass filter [7] using a section of doubly inductively compensated parallel-coupled lines as shown in Fig. 1 is introduced. The proposed filter has the high performance to suppress the signal transmission in transition and stop band frequencies with compact size and convenient close form equation. Section II presents the concept of the inductive compensated one-section coupled lines and its application to elliptic low pass filter. The technique can be achieved high-directivity by connecting the inductive in series with coupled port of the parallel-coupled lines, which suitable for elliptic low pass filter implementation. Simulated and measured results of the proposed compensation filter will be illustrated in Section III. The paper is finally concluded in Section IV.

2. Elliptic Low pass Filter with Inductively Compensated Microstrip Coupler

Quarter-wavelength ($\lambda/4$) parallel-coupled lines are usually employed for design and implement verities kinds of microwave circuits such as resonator power combiner/splitter phase shifter and filter circuits [1-2]. Among these circuits, the conventional N-stage coupled-lines band pass filter is the most well known for the researchers because of its many benefits, such as the simple design procedure and structure. However, as the filters circuits are implemented or incorporated with parallel-coupled lines structure it's suffered from spurious responses located at twice the fundamental frequency. These spurious responses cause response asymmetry in the upper and lower stop bands. Another major limitation of mentioned filter circuits are comes from the weak lateral coupling between lines in a conventional structure, which is due to the inhomogeneous nature of microstrip lines. The inhomogeneity of microstrip lines results in unequal even-and odd-mode phase velocities, a condition often rendered worse by manufacturing irregularities in the fabrication process. These limitations can be overcome by either providing different line lengths for even and odd modes or equalizing the modal phase velocities [2, 5]. It is well known that the addition of a short uncoupled line section at either end of a coupled line section can result in improved filter characteristics [1]. Structures so far reported in the literature based on this filter design approach include wiggly-line filters, uniplanar coupled bandgap filters, corrugated coupled microstrip coupled lines filters, meandered parallel coupled-line filters, cascaded band-reject filters, and split-ring filters [2-7]. However, these structures either increase the circuit complexity by recalculating the design parameters or require unrealistically tight fabrication tolerances to be effective.

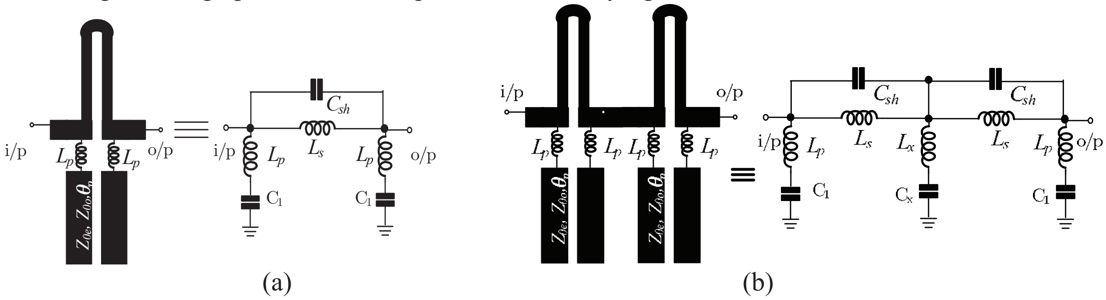

Fig. 2. Schematics of the proposed (a) one and (b) two section low pass filters with inductively compensated coupled lines

In this paper, the low pass filter with inductively compensated parallel coupled lines low pass filter as shown in Fig. 1 b) is proposed. This circuit is achieved by modified a circuit with conventional coupled lines low pass filter as shown in Fig. 1 a) by adding compensation inductors at input and coupled port of the coupled lines. The compensation inductor (L_p), which can implemented in either lumped or distributed forms use for adjusted so that 90^o phase difference between the direct (port 4) and coupled (port 2) ports at centre frequency of f_0 is obtained are selected by [11]:-

$$L_p = \frac{1}{2\pi f_0}\mathrm{Im}\left\{\frac{-Z_{0e}\left(Z_{0o}^2+Z_0^2\right)\sinh\theta_o + Z_{0o}\left(Z_{0e}^2+Z_0^2\right)\sinh\theta_e - 2Z_0^3\Im}{Z_0\left(Z_{0e}\sinh\theta_o + Z_{0o}\sinh\theta_e\right) - Z_0^2\Im}\right\} \quad (1)$$

where $\Im = \cosh\theta_e - \cosh\theta_o$, Z_0 is the characteristic impedance of the coupled lines,

Z_{0e} is the even-mode characteristic impedance of the coupled lines,

Z_{0o} is the odd-mode characteristic impedance of the coupled lines,

ε_{effe} is the even-mode effective dielectric constant,

ε_{effo} is the odd-mode effective dielectric constant,

$\theta_e = \pi/2$ is the even-mode electrical length of the coupled lines,

and $\theta_o = (\pi/2)\Theta$ = is the odd-mode electrical length of the coupled lines and $\Theta = \sqrt{\varepsilon_{effo}/\varepsilon_{effe}}$

Fig. 2 shows the proposed one and two sections low pass filters based on inductively compensated parallel-coupled lines, the compensation inductors (L_p) are synthesize from high impedance microstrip transmission line. The series capacitors (C_{sh}) are come from fringing of the weak lateral coupling between the lines of input and output ports structure, while the series inductors (L_s) are come from the high impedance U-shape transmission line. The proposed circuits can be replaced by LC equivalent circuit as shown in Fig. 3 a) and 3 b). Where the LC equivalent circuit of the proposed circuits are look similar to the elliptic- transfer function low pass filter.

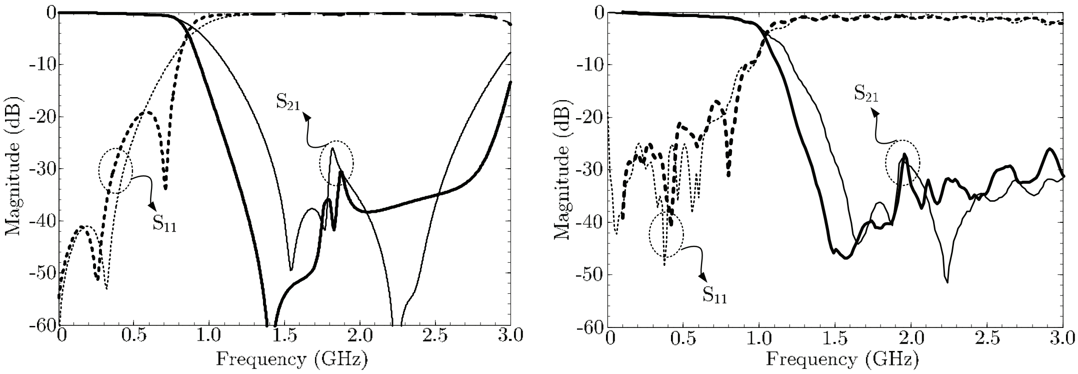

Fig. 3. (a) Simulated and (b) measured results of the proposed (a) one (——) and (b) two sections (━━) low pass filter with inductively compensated parallel coupled lines

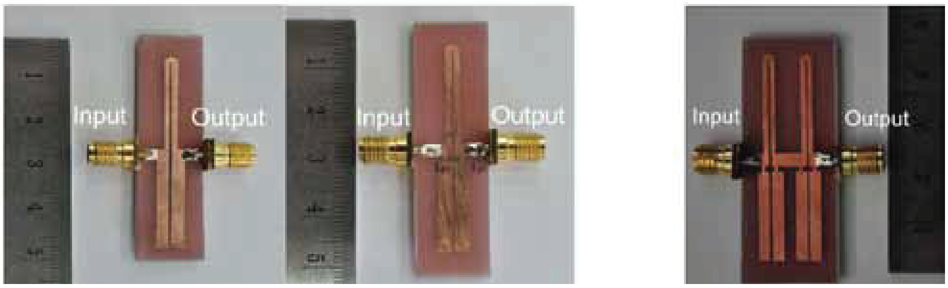

Fig. 4. PCB photographs of (a) one and (b) two sections low pass filter with inductively compensated parallel coupled lines

Table 1. Parameters of the designed frequency doubler circuit at input and output frequencies of 0.9GHz

Techniques	Components	Coupler's length (θ,rad)	W,S,L (mm)
Uncomp.	-	0.25π	2.45, 0.35,20.0
Compensated Inductors	L_p = 1.2nH	0.22π	2.45, 0.33,19.0

3. Design and Experimental Results

To demonstrate the proposed technique, low pass filters designed with a section of λ/8 wavelength parallel-coupled lines at the cut off frequency of 0.9 GHz are design and implemented. The employed parallel-coupled lines are 10-dB ordinary and inductively compensated voltage coupling factor on FR4 substrate. The compensation inductors in both circuits were calculated from (1) by using the coupled line electrical parameters at f_c, which are 1.2 nH. The design and simulation process were done by using

Sonnet Lite™. The design results have been summarized as shown in Table 1. The EM simulation is comparison between the simulated results of one and two sections of the proposed LPF. It is obviously shown in Fig. 3 a) that, the transition band of one section elliptic LPF was slightly decreased than two section low pass filter circuit. As the section of the proposed circuit is increased transmissions zero frequencies is shifted closely to cut-off frequency, lead to more sharply transition band and stop band suppression.

The measured results are obtained from the vector network analyzer (E5062) calibrate from 0.3 to 3 GHz. The proposed technique achieves less than 0.2 dB insertion loss and less than 20 dB return loss performance at pass band frequencies. In comparison with one section circuit, two section circuits have a better frequency performances, the suppression performance in transition band is more than 20dB improvement. So, the proposed inductive compensated low pass filter can be simply used for numerous microwave application circuits. It provides a sharp cut off frequency response and low insertion loss with a compact size. The photographs of the PCB of the proposed one and two sections low pass filters are shown in Fig. 4 a) and 4 b), respectively.

4. Conclusion

This paper presents a simple design technique for the elliptic transfer function low pass filter based on one section of inductively compensated parallel-coupled lines. The proposed filters have high suppression performance to suppress the signal transmission in transition and stop band better than the filter based on ordinary coupled lines. Also, the design procedures are convenient with the closed form design equation. To compare the techniques performance, measured results of 0.9 GHz cut off frequency LPF with one and two sections low pass filter are compared. The measured results obtained from the proposed LPF exhibit 0.2 dB insertions, less than 20 dB return loss and more suppression performance than 35 dB at 1.8 GHz. Two section low pass filter provides a sharp cut off frequency response and low insertion loss with a compact size. In addition, it is believed that the proposed technique can be simply modified to be microwave filters, which are suitable for various circuits in many modern wireless and microwave systems.

Acknowledgements

This work is financially supported by Faculty of Technology, Institute of Research and Development, Udonthani Rajabhat University. The authors are also grateful to acknowledge Faculty of Industrial and Technology, Rajamangkala University of Technology Isan, Sakon Nakorn Campus for supporting the circuits measurement.

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