Available online at www.iseec2012.com

I-SEEC 2012

Proceeding - Science and Engineering (2013) 247–251

Proceeding
Science and Engineering

www.iseec2012.com

Science and Engineering Symposium
4th International Science, Social Science, Engineering and Energy Conference 2012

Microstrip Directional Couplers with Doubly Centrally Located Inductive Compensation

R. Phromloungsri[a,*], S. Sonasaeng[b], N. Angkawisittipan[c] , N.Thamvongsa[a]

[a]*Department of Electronics Engineering, Faculty of Technology, Udonthani Rajabhat University, Udonthani, 41000, Thailand*
[b]*Department of Electronics Engineering, Faculty of Engineering, Udonthani Rajabhat University, Udonthani, 41000, Thailand*
[c]*Department of Electrical Engineering, Faculty of Engineering, Muang, Nongbualamphu, 39000, Thailand*

Abstract

This paper presents a novel technique to design a high-directivity parallel-coupled lines using the doubly compensation inductors located centrally at the microstrip parallel-coupled lines. The configuration based on the technique located series inductors at the centre of parallel lines is proposed. The practicable feasibility of the technique is demonstrated at 0.9 GHz on Arlon AD350A substrate, where the directivities obtained from measured results are the broadband improvements of more than 6 dB as compared with uncompensated coupler.

Keywords : inductive compensation technique, series centrally located, inductivity element

1. Introduction

Quadrature microstrip parallel-coupled lines are widely utilized for many wireless and microwave circuits such as Marchand balun, filters, resonators and various microwave integrated circuits because they can easily be incorporated into and implemented with other circuits [1],[2]. However, many unwanted effects in those circuits are already mentioned and unavoidably, which is a result from the inhomogeneous dielectric of the substrate. Through this structure, phase velocity of the even-mode in microstrip parallel-coupled lines is slightly lower than the odd-mode phase velocity. Which in turn lead the parallel-coupled lines exhibits poor directivity. Through having various disadvantages, parallel-coupled lines is still preferable in microwave circuits design due to its integrating capability. Many techniques have been developed to compensate the inequality of modes phase velocities of the parallel couplers. These techniques can be classified into two main categories, which are lumped and distributed compensation approaches. The lumped compensation techniques can be categorized into two well known techniques, which are capacitive [5],[6] and inductive [7],[8] compensation techniques. The distinct advantage of the lumped compensation technique is its simple design procedure because the closed-form design equations can be derived. But, the important disadvantages of the techniques are from the lumped components'

* Corresponding author. *E-mail address:* icurvip@yahoo.com

parasitic and difficulty in layout [9]. As the coupler sizes' is considered, the lumped compensated parallel-coupled lines is about the uncompensated parallel-coupled lines, since the length compensated parallel-coupled lines is shorter than that of the uncompensated coupled lines. The methodology based on the distributed techniques is to modify either the parallel-coupled line structures [1],[2] ,dielectric layer [3], or ground plane patterns [4], such that the phase velocities of both modes are equalized. No external components or extra spaces are needed for this approach. The main disadvantage of this approach is lack of closed-form design equations, meaning that the design task relies heavily on the electromagnetic simulation (EM) stage which in turn consumes much effort and computing time. Moreover, techniques based on these approaches are often not suitable for some standard fabrication processes, thus more cost demand is unavoidably required.

2. Microstrip Coupled-Lines with the series doubly compensation inductors located at the center

Fig. 1a) and b) show the singly and doubly-inductive compensated couplers, which were recently proposed. The coupled lines in Fig. 1a) and b) are assumed to be symmetric. Clearly that the singly- and doubly-compensated coupled lines are not symmetry as the connecting position of the compensated inductors. The asymmetry in these structures makes them unsuitable for some applications needed symmetry, for example a six-port network [xx]. In fact, the symmetry structure of inductive-compensated coupled lines can be obtained. The structure is shown in Fig. 1.

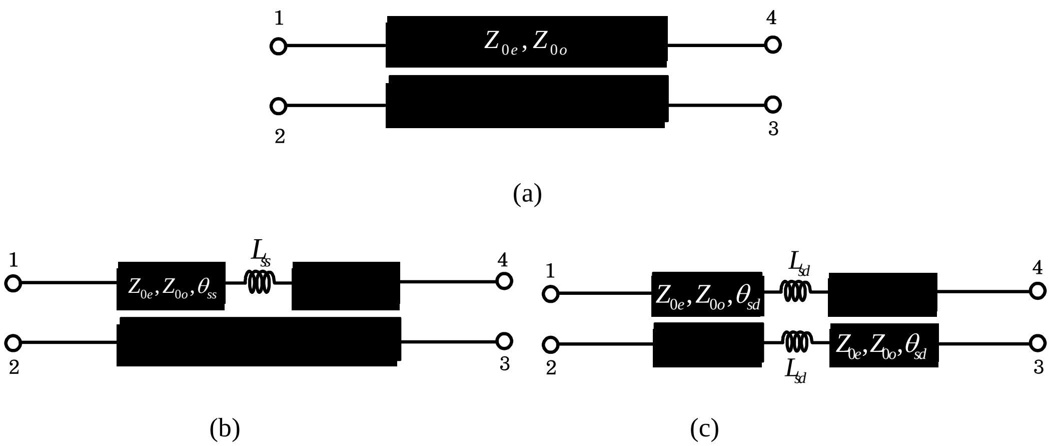
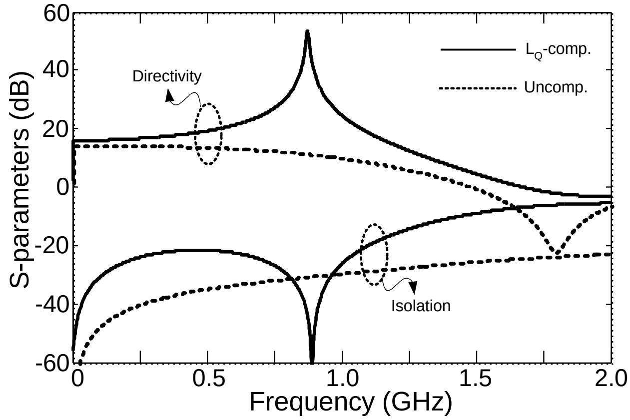


Fig. 1. Schematics of the proposed a) conventional parallel coupled lines, b) singly- c) doubly-inductive-series parallel coupled lines

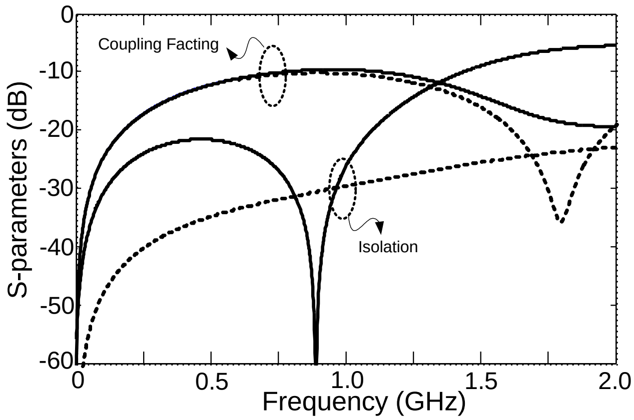
As shown in Fig. 1c), four equal inductors denoted by LQ are connected in series at all coupled lines' ports. The uncompensated coupled lines ports are denoted by port 1-4 where the ports of the inductive-compensated coupled lines are labeled as port 1'-4', as shown in Fig 1c). The isolation coefficient (S13), in term of coupler electrical parameters (Z0, Zoe, Zoo, εeffe, εeffo), is evaluated by terminating port 2', 3', and 4' with the characteristic impedances of the lines Zo, while port 1' is terminated with voltage source with the output impedance Zo. Assuming that the uncompensated parallel-coupled lines are symmetrical, hence the Z-parameters of the parallel-coupled lines can be characterized completely by just four elements of the uncompensated parallel-coupled lines' Z-parameter matrix denoted by Z11, Z12, Z13, and Z14. Applying the two-port network theory to the circuit of Fig. 1c), the Z-parameters of the proposed compensated parallel-coupled lines (ZQ) in the matrix form can be written as :- Equation (3) offers a closed-form expression to design the compensating inductances for achieving high directivity at the center frequency f0. However, the compensating inductances retard phase of the propagated signal, the zero-isolation frequency is shifted to frequency which is lower than the original frequency. Similar to the other lumped compensation techniques, the center frequency can be simply shifted back to original frequency by modifying the electrical length of the compensated parallel-coupled line as shown:-

3. Design and Result

To demonstrate performance of the proposed technique, 10 dB uncompensated and the proposed inductive-compensated microstrip parallel-coupled lines operating at f_o 0.9 GHz on RF60-0600 microwave substrate were designed and simulated. The compensation inductors (L_Q) and the shorten electrical lengths were calculated from (3) and (4), which are 2.3 nH and 0.45π. The circuit based simulation a result is shown in Fig. 3(a). At least 25 dB directivities are achieved from 0.7 to 1.1 GHz. In Fig. 3(a) it is shown that at operating frequency, the technique provides directivity of 46 dB, which is more than 30 dB over the uncompensated coupled lines. The isolation can achieve more than 50 dB at the center frequency. In Fig. 3(b) for the RF60-0600 substrate, the coupling is slightly affected, which is less than 0.5 dB at frequencies



(a)



(b)

Fig.3. Simulated results performances of uncompensated and the proposed quadruply-inductive compensated parallel-coupled lines

Gains of the previous lumped design cases [1],[4],[5]. At frequencies more than the center frequency coupling level of the proposed coupler is slightly more than that of the uncompensated coupler. Moreover, at center frequency all-ports return loss is less than -60 dB and less than 30 dB over 40% operating bandwidth. Proving of the developed formulas are demonstrated by the design examples of 10-dB uncompensated and the proposed nductive compensated parallel-coupled lines deigned at fo of 0.9 GHz on RF60 substrate were designed and fabricated. The design parameters of prototype of uncompensated and the proposed couplers corresponded to equations (3), (4) were listed in Table II. Note that, since the proposed couplers' length is shorter than L =□0/4 that of uncompensated coupler. So the coupling level will be lower than 10-dB. To enhance the coupling, the W and S must be slightly narrowing. The EM simulator Sonnet-Lite™ is used to simulate the couplers and meander lines inductors behavior. Fig. 4 shows EM simulated results of the proposed coupler. An excellent directivity, isolation and return loss improvement can be observed.

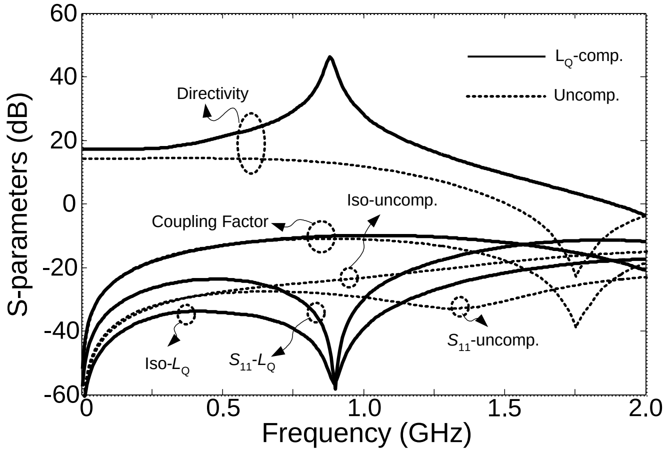


Fig. 4. EM simulated results of uncompensated and the proposed quadruply-inductive compensated coupler

The EM simulated directivity is 43 dB, isolation and return loss at frequency fo, are more than 55 dB, which is more than 25 dB improvement compare to the uncompensated coupler. In this work, all measurement is done by HP8753E vector network analyzer calibrated from 0.1 to 2.0 GHz. Fig. 5 show that all the measured results are matched excellently with the EM simulated results. The measured coupling is -10 dB which has less than 0.5 dB variation over 30 % bandwidth. The measured directivity can achieve 43 dB and the isolation has a more than 30 Db improvement to compare with the uncompensated parallel-coupled lines. The measured directivity and isolation improvement are significant and matches excellently with the simulations. The photograph of the PCB of the proposed quadruply-inductive compensated coupler is shown in Fig. 6.

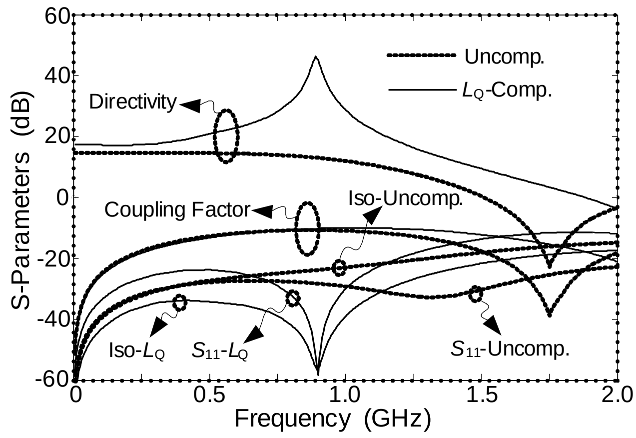
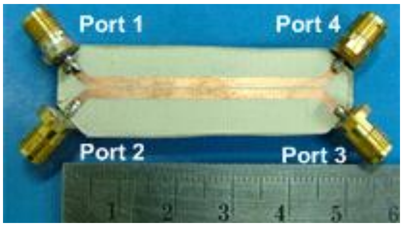


Fig. 5. Measured results of uncompensated and the proposed quadruply-inductive compensated coupler



(b)

Fig. 6. PCB photographs of (a) uncompensated and (b) the quadruply-compensated coupler

4. Conclusion

This paper presents a lumped-distributed ring resonator based on a coupled-fed network. The size of the proposed circuit is small, comparing to the conventional circuit. The spurious response problem occurred in the conventional circuit are effectively alleviated by the inductors in the proposed ring resonator. The lumped capacitors are used to tune the ring resonator resonant at the desired frequencies. The proposed ring resonator can be simply modified to be microwave oscillators tunable, which are suitable for various circuits in many wireless and microwave systems.

References

[1] Li, J.L., and Wang, B.Z., "Novel design of Wikison power dividers with arbitrary power division rati ons", IEEE Trans. Ind. Electron., 2011,58, (6), pp. 2541-2546.

[2] R. Phromloungsri, M. Chongcheawchamnan, and I. D. Robertson, "Inductively compensated parallel-coupled microstrip lines and their applications", IEEE Trans. Microwave Theory Tech.,2006,54, (9), pp. 3571-3582.

[3] Kou, J.T., Lok, U.H., and Wu, M.H., "Novel corrugated coupled-line stage with ideal frequency response and application to bandpass filter design with muti-hamonic suppression", Dig. IEEE MIT-S, Honolulu, HI, USA, 2007, pp. 553-556.

[4] Lopetegi, T. and et al, " Microstrip "wiggly-line" bandpass filter with multispurious rejection", IEEE, Micro. Wirel. Compon. Lett., 2004, 14, (11), pp. 531-533.

[5] V. Chamnanphai, R. Phomloungsri, and M. Chongcheawchammnan, "Design six-port reflectometer with singly inductive-compensated coupled lines" the 3rd 2006, ECTI Annaual Con. Thailand, vol. 2, pp. 119-123, 10-13 May, 2006.