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# PROCEEDINGS

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Tianjin University of Science and Technology, China

**Kaide Hotel 4th Floor Room Kaixuan**

| **Session 4-B: Communications and Network, Internet of things\Microwave\Information Display** |
|---|
| 14:00-17:00, Saturday, September 21, 2019<br>*Session Chairs:* Ji-Hoon Lee (Chonbuk National University, Korea)<br>Yuan Wang (Tianjin University of Science and Technology, China) |

- ID 6. Design and Development of Water Quality Inspection System Based on GPS Positioning
  Yang Yu, Yunxi Gu, Zhipeng Li, Wenqi Guo, Lin Hou and Chunfeng Wang
  Tianjin University of Science and Technology Tianjin, China

- ID 8. Research and Application of 4G Technology in Banking System
  Lin Hou, Yu Yang Sheng and Yu Yang
  Tianjin University of Science and Technology Tianjin, China

- ID 9. Switchable Lightening and Reflective Display Device using Dichroic Dye
  Jiyeon Kim, Gwangsik Sin, Soohyun Oh, Jaemu Oh, Jinyoung Jeong and Ji-Hoon Lee
  Chonbuk National University, Korea

- ID10. Optical Diode Effect of Nematic Liquid Crystal containing Plasma-treated Surface
  Jinyoung Jeong and Ji-Hoon Lee
  Chonbuk National University, Korea

- ID17. Anisotropic optical absorber controlling narrow and wide viewing angle of display using a mixture of dichroic dye and liquid crystal
  Ho-Jin Choi, Hyunseung Lee, Seunghee Lim, Sooyoung Park, Seungkil Baek and Ji-Hoon Lee
  Chonbuk National University, Korea

- ID69. λ/4 Transmission Line Using Composite Right/Left Handed Unit Cells for Dual Band Applications
  Qi Wang[1], Jongsik Lim[1] and Yongchae Jeong[2]
  Chonbuk National University[1] and Soonchunhyang University[2] , Korea

- ID 80. Research on Secure Access Technology of Mobile Terminal for Android
  Yiying Zhang, Jing Shang, Yuanlong Ruan, Cong Wang and Song Liu
  Tianjin University of Science and Technology Tianjin, China

# $\lambda/4$ Transmission Line Using Composite Right/Left Handed Unit Cells for Dual Band Applications

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***Abstract*—In this paper, lumped element comprised transmission line with a quarter wavelength ($\lambda/4$) characteristics at arbitrary dual band frequencies has been proposed. The ideal lumped element structure can provide the possibility of composite right/left handed (CRLH) transmission line for monolithic microwave integrated circuit application. Proposed ~~structure of~~ $\lambda/4$ CRLH line has been mathematically analyzed and verified by simulation at dual bands of 2.4 GHz for Wi-Fi application and 3.5 GHz for 5G communication system. By the simulations, the phase responses of CRLH line are obtained as $-\pi/2$ and $\pi/2$ at designed frequencies, respectively.**

***Keywords—CRLH, dual band, lumped element.***

## I. INTRODUCTION

Recently, with the tremendous demands of wireless communication system, wireless communication circuits and devices are drawing more and more interest. The needs for high data rate, delivering high quality, low latency, and multiband applications have brought many challenges for wireless communication system development.

Composite right/left handed (CRLH) transmission line (TL) is a TL composed of the periodic repetition of a unit cell comprising a series inductance and a shunt capacitance as well as a series capacitance and a shunt inductance. The equivalent lumped element (LE) model of the LH TL exhibits positive phase response (phase lead). On the other hand, the RH TL has negative phase response (phase lag). These attributes are applied to the design of a dual-band $\lambda/4$ TL, in which the phase response of the CRLH TL is manipulated to yield electrical lengths of 90 at two arbitrary frequencies.

The phase response of CRLH is controllable by adjusting the values of the lumped elements in unit cell, and is no longer linearly proportional to frequency like the conventional transmission line. As a result, CRLH structures have been widely adopted and implemented for multiband applications [1][2]. However, these applications chose the phase responses of $-\pi/2$ and $-3\pi/2$ for dual band $\lambda/4$ TL at the dual operating frequencies, which caused a bulky circuit size due to the chosen negative phases depending strongly on the right-handed TLs. To reduce the size of CRLH lines, positive phase $\pi/2$ of CRLH has been proposed in that positive phase are caused by the left handed part of CRLH, hence the required lengths of right handed transmission lines became shorter [3]-[5]. Nonetheless, the circuit still occupies a certain size because of the realization of the RH part by TL.

In order to minimize the circuit size as small as possible, lumped element comprised structure is a possible solution. This paper proposes a realizable structure to implement with lumped elements. The proposed structure is analyzed by CRLH theory and simulation results shows that this structure can satisfy the design requirements and is promising for more applications in monolithic microwave or RF intergrated circuit(IC) design.

The paper is structured as follows: chapter II shows the theory of dual band CRLH and design purpose. The proposed structure will be introduced in chapter II, where the analysis procedure will be shown and discussed. After that, chapter III will provide the simulation results with performance analysis and assessment. Finally a brief summary will be concluded in conclusion part.

## II. CRLH THEORY AND PROPOSED STRUTURE

The unit cell of the CRLH is shown in Fig. 1[1]. In this figure, $L_R$ and $C_R$, denote serious inductance and shunt capacitance of right-handed (RH) cells while $C_L$ and $L_L$ denote serious capacitance and shunt inductance of left-handed (LH) cell, respectively. This unit cell topology is composited from a RH unit cell and a LH unit cell both with L-type connection.

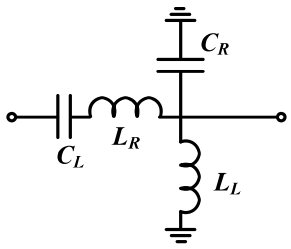
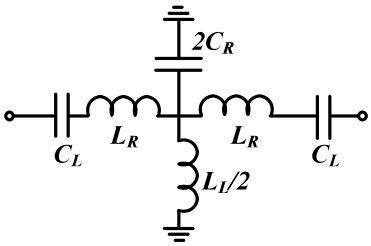



Fig. 1. CRLH unit cell

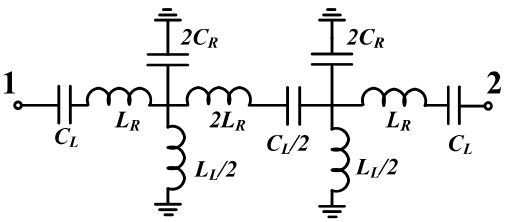
The phase response of CRLH is the superposition of the RH and LH cell phases. The design frequencies are selected at first, then the values of lumped elements can be calculated according to the required phase responses [3].

$$\phi_{CRLH} = -\omega\sqrt{L_R C_R} + \frac{1}{\omega\sqrt{L_L C_L}} \quad (1)$$

Fig. 2 shows the back-to-back connection of 2 unit cells and 4 unit cells. This connection provides a symmetricity as the conventional transmission line is symmetric itself. 4-unit cell structure is adopted as our proposed structure because the cascading of more unit cells resembles more closely the homogenous transmission lines and it can provide a wider passband.




(a)




(b)

Fig. 2. Structures of CRLH line using: (a) 2 unit cells (b) 4 unit cells

## III. SIMMULATION AND RESULT ANALYSIS

To show the validity of the proposed $\lambda/4$ CRLH line, designed frequencies are chosen to be 2.4 GHz for Wi-Fi application and 3.5 GHz for 5G communication system. Then all lumped element values can be calculated by dual band CRLH theory and calculated values are shown in Table I. ADS (Advanced Design System, Keysight) was used to simulate the circuit. The insertion losses, return losses, and phase responses were checked at designed frequencies. The simulation results are shown in Figs. 3 and 4, respectively. From the results, we can see our proposed $\lambda/4$ CRLH line can pass the signal very well and the phase responses are 92.4° and -92.4° at designed frequencies.

TABLE I

CALCULATED LUMPED ELEMENT VALUES

| LE | $C_R$ | $L_R$ | $C_L$ | $L_L$ |
|---|---|---|---|---|
| value | 1.1 pF | 2.8 nH | 1.1 pF | 2.6 nH |

These characteristics imply that this $\lambda/4$ CRLH line is operating with the electrical length of $\lambda/4$ at arbitrary dual frequencies that the designer can choose. The *S*-parameters shows broad band characteristics, which are realized by the cascading structure of 4 unit cells of CRLH.

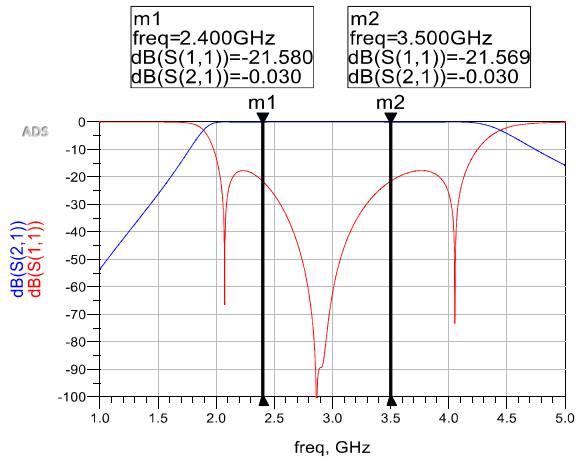



Fig. 3. *S*-parameters of proposed λ/4 CRLH line

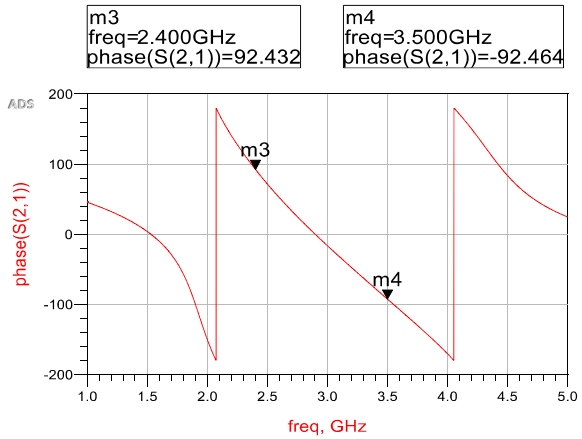



Fig. 4. Phase response of proposed λ/4 CRLH line

## IV. CONCLUSION

In this paper, lumped element comprised transmission line with a quarter wave length ($\lambda/4$) characteristics at arbitrary dual band frequencies is proposed. Proposed structure of $\lambda/4$ CRLH line has been mathematically analyzed and verified by simulation. This structure can be applied for the design of multiband operation such as dual band branch line coupler or dual band antenna system where $\lambda/4$ transmission line is needed at arbitrary dual frequencies.

Furthermore the idea of lumped element structure provides the possibility for CRLH transmission line in monolithic microwave or RF IC design, which can satisfy the requirement for multiband system design in wireless communication system nowadays.


## ACKNOWLEDGMENT

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