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Session TH1B : Communications and Network **10:00-12:00, Thur. October 30, 2014** **Session Chair : Sooyoung Kim (Chonbuk National University, Korea)** **Chuanlei Zhang (Tianjin University of Science and Technology, China)**	**Room NO. 212**
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	Meixiang Zhang and Sooyoung Kim Division of Electronics Eng. Chonbuk National University, Korea
TH1B-2	**Research on Network Topology and Framework of the Perception Layer in IOT**
	Wei-Dong Fang1, Xiu-Zhi Wang1, Zhi-Dong Shi1, Guo-Qing Jia2, Ying Ma2 Lian-Hai Shan3 and Chuanlei Zhang4 1School of Com. and Information Engineering, Shanghai University, China 2College of Physics and Electronic Information Engineering, Qinghai University for Nationalities Xining, China 3Shanghai Internet of Things Co., LTD, China 4School of Computer Science and Information Engineering, Tianjin University of Science and Tech, China
TH1B-3	**Communication Networks for Wind Turbine Monitoring based on Infrared Camera**
	Shahid Hussain, Mohamed A. Ahmed, Young-Chon Kim Department of Computer Engineering Chonbuk National University, Korea
TH1B-4	**Novel Power Control Scheme for Interference Mitigation in Macro-Femtocell Heterogeneous Network**
	Sangmi Moon, Saransh Malik, Hun Choi, Cheolhong Kim, Jinyoung Kim and Intae Hwang Dept. of Electronics and Computer Engineering, Chonnam National University, Korea
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	Aladdin Djouama and Myoung-Seob Lim Division of Electronics & Information Engineering, Chonbuk National University, Korea
TH1B-6	**Block Circulant Toeplitz Jacket Matrix for Correlated MIMO Channel**
	Han Hai1, Moon Ho Lee1, Yongchae Jeong1, Yier Yan2, Liting Huang2 and Jae Seung Yang3 1Division of Electronics Engineering, Chonbuk National University, Korea 2School of Mechanical and Electrical Engineering, Guangzhou University, China 3Computer Engineering Daejin University, Korea

Session TH1C : Microwave and Antenna **10:00-12:00, Thur. October 30, 2014** **Session Chair : Jongsik Lim (SoonChunHyang University, Korea)** **Heungjae Choi (Cardiff University, United Kingdom)**	**Room NO. 209**
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	Heungjae Choi, Jerome Cuenca, Jon Hartley and Adrian Porch School of Engineering, Cardiff University, United Kingdom
TH1C-2	**Tunable Negative Group Delay Circuit With Improved Signal Attenuation**
	Junhyung Jeong, Seungwook Lee, Girdhari Chaudhary and Yongchae Jeong Division of Electronics and Information Engineering, Chonbuk National University, Korea
TH1C-3	**Assessment of Machine Oil Quality by Microwave Cavity Perturbation Method**
	Jon Hartley, Jonny Lees, Jerome Cuenca and Heungjae Choi Centre for High Frequency Engineering, School of Engineering, Cardiff University, United Kingdom
TH1C-4	**Design of a Size-Reduced Ring Hybrid Coupler using Double-Layered Substrate and Ground Contact-Free Defected Ground Structure**
	Jongsik Lim1, Hanjoo Do1, Seok-Jae Lee2, Sang-Min Han2 and Dal Ahn2 1Department of Electrical Engineering, SoonChunHyang University, Korea 2Department of information and Communication Engineering, SoonChunHyang University, Korea
TH1C-5	**Microwave Detection of Photodielectric Effects in Antimony Tin Oxide**
	Jerome Cuenca, Heungjae Choi, Jon Hartley and Adrian Porch Centre for High Frequency Engineering, School of Engineering, Cardiff University, UK
TH1C-6	**A Design of Circular-Meander Structure Antenna for MICS Band**
	Jong Bin Park1, Dong Suk Lee1, Robert Hitchcock2, and Dong Sun Park3 1Department of Electronic&Information Engineering, Chonbuk National University, Korea 2Department of Bioengineering,University of Utah, USA 3Department of Electronics Engineering, Chonbuk National University, Korea

Tunable Negative Group Delay Circuit With Improved Signal Attenuation

Junhyung Jeong, Seungwook Lee, Girdhari Chaudhary, and Yongchae Jeong

Division of Electronics and Information Engineering,
Chonbuk National University,
Jeonju, Republic of Korea
E-mail: jjunh05@jbnu.ac.kr

Abstract

In this paper, a design of tunable negative group delay circuit (NGDC) with improved signal attenuation is presented. The proposed circuit is based on reflective parallel RLC circuit and the group delay (GD) can be tuned with help of variable capacitor. To maintain constant resonance center frequency due to capacitance variation, variable inductor is applied in the proposed NGDC. To get the variable capacitor and inductor, varactor diode and transmission line terminated with varactor diode, respectively, are used. Both design equations and design procedures are presented. The measured GD and insertion loss variation range is -2 ~ -20 ns and 4.45 ~ 23.2 dB.

Keywords- ***negative group delay circuit, varactor diode, transmission line.***

I. Introduction

Since after discovery of negative group delay (NGD) concept, it has been applied to the various applications of microwave communication system [1]-[5]. For example, by inserting negative group delay circuit (NGDC) on a common path in the feed-forward amplifier, it is possible to remove group delay (GD) circuit located in the output port of main power amplifier, which results in enhancements of overall efficiency and output power [6]. The previous NGDC can provide tunable NGD. However, main drawback of NGDCs have high insertion loss [7]. This high insertion loss is a limitation for applying NGDCs in microwave communication systems.

This paper presents the analysis and design of tunable NGDC with improved signal attenuation. For this purpose, the variable capacitor and inductor are implemented with varactor diode and transmission line (TL) terminated with the varactor diode, respectively.

II. Mathematical Analysis

Fig. 1(a) shows the structure of proposed tunable NGDC. It consists of 3-dB hybrid coupler, varactor diode, and TL terminated with the varactor diode, respectively. The equivalent circuit of coupling and through port circuits is shown in Fig. 1(b) as an 1-port parallel RLC equivalent circuit. In this equivalent circuit, the varactor is expressed along with parasitic components such as junction capacitance C_{VP}, junction resistance R_{VS}, and lead inductance L_{VP}.

At the resonant frequency, the GD and insertion loss expressions can be obtained as follows.

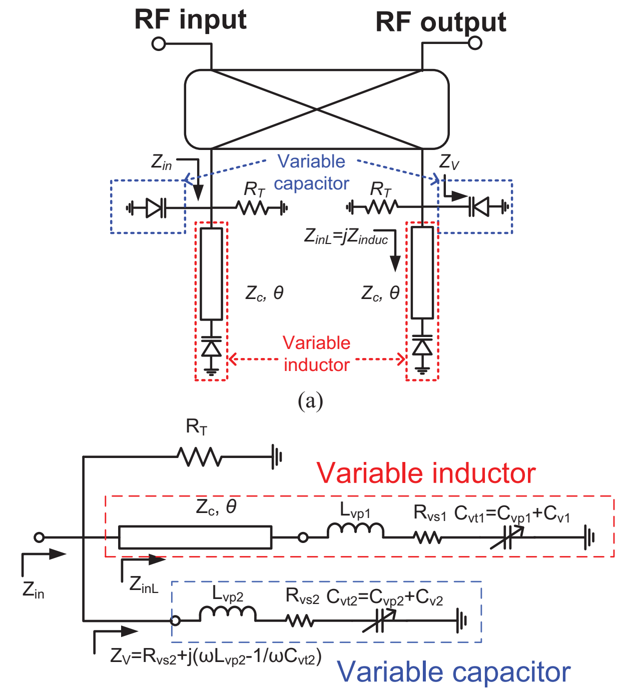


Fig. 1 (a) Proposed tunable negative group delay circuit with improved signal attenuation structure and (b) equivalent circuit of 1-port parallel RLC with varactor diodes.

$$GD\big|_{\omega=\omega_0} = \frac{Z_0 R_T^{\,3} Z_V \left(Z_{induc} + \omega_0 Z_{induc}'\right)}{Z_L\left(R_T^{\,2} - Z_0^{\,2}\right)} \tag{1}$$

$$\left|S_{21}\right|_{\omega=\omega_0} = \frac{R_T - Z_0}{R_T + Z_0} \tag{2}$$

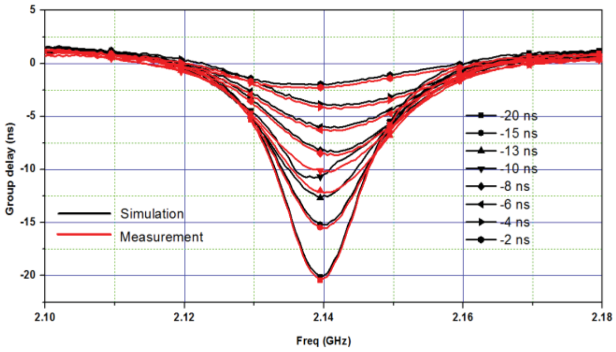
where

$$Z_{induc} = jZ_C \frac{\omega_0 C_{vt1} Z_C + \omega_0^2 C_{vt1} L_{vp1} - 1}{\omega_0 C_{vt1} Z_C - \omega_0^2 C_{vt1} L_{vp1} + 1} = \frac{1}{\omega_0 Z_V}\Bigg|_{\omega=\omega_0} \tag{3}$$

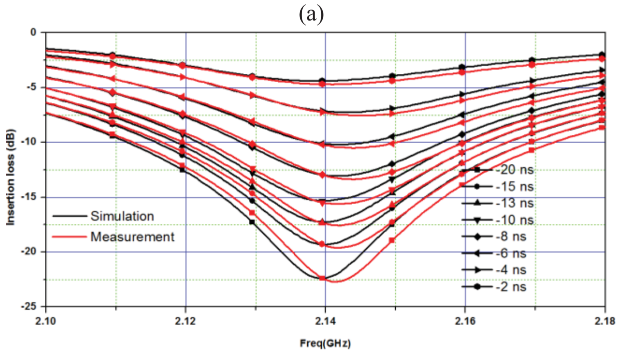
$$Z_{induc}' = Z_C \frac{-2C_{vt1} Z_C\left(\omega^2 C_{vt1} L_{vp1} - 1\right) + 4\omega^2 C_{vt1}^{\,2} L_{vp1} Z_C}{\left(\omega\, C_{vt1} Z_C - \omega^2 C_{vt1} L_{vp1} + 1\right)^2} \tag{4}$$

$$C_{vt1} = \frac{Z_C \omega_0 Z_V + 1}{\left(\omega_0^{\,2} Z_V Z_C^{\,2} + \omega_0^3 Z_V L_{vp1} Z_C + \omega_0^2 L_{vp1} - \omega_0 Z_C\right)} \tag{5}$$

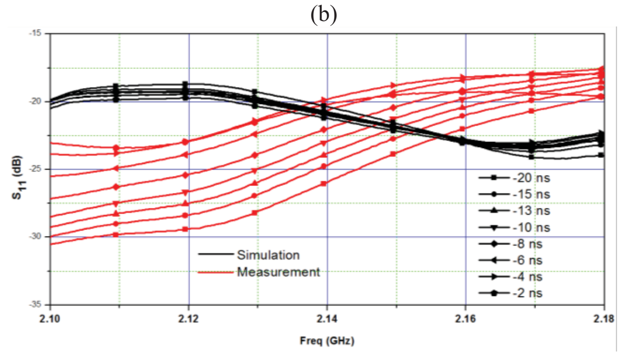
From (1), NGD can be obtained for $0 < R_T < Z_0$. It is also clear that the GD can be tuned with variable R_T. Also Z_V and Z_{induc} can vary GD, respectively, but these values must have trade-off relation for maintain the constanct resonance frequency.



(a)



(b)



(c)

Fig. 2. Simulation and measurement results: (a) negative group delay, (b) insertion loss, and (c) return loss characteristics.

Expressions (3) and (4) are input impedance and differential value of variable inductor, respectively, where these values can be selected by (5). In (5), C_{vt1} is varacter diode capacitance of variable inductor for maintaining the constanct resonance frequency

As senn from (2), the signal attenuation characteristic is function of R_T at resonant frequency. The signal attneuation is increased when R_T is closer to Z_0. Therefore, the NGD with improved signal attneuation can be obtained by low resistance .

III. Simulation and Measurement

For experimental validation, NGDC with GD variation of -2~-20 ns at center frequency (f_0) of 2.14 GHz for WCDMA downlink band was designed. The circuit is fabricated on the substrate RT/Duriod 5880 from Rogers Inc. with a dielectric constant (ε_r) of 2.2 and thickness (h) of 31 mils. The varacter diode SMV 1233 from Skyworks for the variable capacitor and TL with characteristic impedance of Z_c=80 Ω and electrical length of θ=45° for variable inductor were used. Parasitic components (C_{VP}, R_{VS} and L_{VP}) of varactor diode from the data sheet are 0.8 pF, 1.3 Ω, and 1.5 nH respectively.

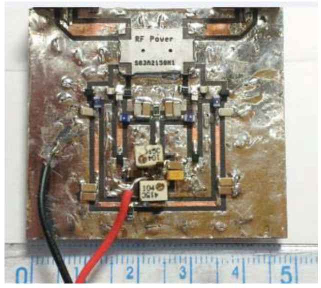


Fig. 3. Photograph of fabricated circuit.

Fig. 2 shows the simulated and measured results of the fabricated tunable NGDC with improve signal attenuation. The measured results are well agreed with the simulation results. From Fig. 2(a), the GD variation is from -2 ns to -20 ns at f_0. The measured insertion loss variations is shown in Fig. 2(b), where its magnitude varies from 4.45 dB to 23.2 dB. The measured return loss characteristics are higher than 17.5 dB for overall tunable range as shown in Fig. 2(c). Fig. 3 shows the photograph of fabricated circuit.

IV. Conclusion

This paper presented analysis and design of tunable negative group delay circuit with improve signal attenuation for WCDMA downlink band. The proposed circuit showed the group delay variation of -2 to -20 ns at the center frequency. For group delay of -20 ns, the insertion loss in proposed work have only 23.2 dB whereas 35 dB and 46.12 dB in [6] and [7]. Therefore, the proposed work provides an improvement in an insertion loss as compared to conventional circuits and therefore, reduce a burden of general purpose gain compensating amplifiers. The proposed circuit is expected to be applicable in various microwave communication systems.

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