2016 IEEE Radio & Wireless Week

FINAL PROGRAM

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24-27 January, 2016

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MONDAY, 25 JANUARY 2016

RWW Session: MO1A

RWW Distinguished Lectures I

Chair: Rashaunda Henderson, UT Dallas
Co-Chair: Hermann Schumacher, University of Ulm

Room: Salon A

SiRF Session: MO1B

5G Communication Technology

Chair: Larry Larson, Brown University
Co-Chair: Julio Costa, Qorvo

Room: Salon B

PAWR Session: MO1C

RF Power Amplifier Modeling and Design Approaches

Chair: Jose Pedro, Aveiro University
Co-Chair: Gayle Collins, Intel

Room: Salon C

RWS Session: MO1D

High-Speed & Broadband Wireless Technologies

Chair: Swaminathan Sankaran, Texas Instruments
Co-Chair: Sergio Pacheco, NXP

Room: Salon F

08:00

MO1A-1 New Frontiers in Terahertz Technology

Mona Jarrahi, University of California Los Angeles, Los Angeles, United States

Abstract: In this talk, I will introduce a game changing technology that enables high performance, low cost, and compact terahertz spectroscopy and imaging systems for various chemical identification, material characterization, security screening, biomedical sensing and diagnosis applications. More specifically, I will introduce a new generation of optically driven terahertz sources and detectors that offer orders of magnitude higher terahertz radiation power levels and detection sensitivity levels compared to existing technologies.

MO1B-1 mm-Wave Radio a Key Enabler of 5G Communication (Invited)

F. Aryanfar, Samsung Research America, Richardson, United States

MO1C-1 Behavioral Modeling for Digital Predistortion of RF Power Amplifiers: from Volterra Series to CPWL Functions (Invited)

A. Zhu, University College Dublin, Dublin, Ireland

MO1D-1 Fast Outer-loop Link Adaptation Scheme Realizing Low-latency Transmission in LTE-Advanced and Future Wireless Networks (Invited)

T. Ohseki, Y. Suegara, KDDI R&D Laboratories, Inc., Fujimino-shi, Japan

08:40

MO1A-2 Switchable and Tunable Ferroelectric Devices for Adaptive and Reconfigurable RF Circuits

Amir Mortazawi, University of Michigan, Ann Arbor, United States

Abstract: The exponential increase in the number of wireless devices as well as the limited wireless spectrum, pose significant challenges in the design of future wireless communication systems. Adaptive and reconfigurable radios that can change their frequency and mode of operation based on the unused/available wireless spectrum as well as their surrounding environmental conditions have been proposed to address such challenges. This presentation is on the applications of ferroelectric thin film barium strontium titanate (BST), a low loss, high dielectric constant field dependent multifunctional material. Properties and performance of several BST based adaptive and reconfigurable RF circuits will be presented.

MO1B-2 Large-Scale Millimeter-Wave Phased Arrays for 5G Systems (Invited)

G. Rebeiz, University of California - San Diego, La Jolla, United States

MO1C-2 Wideband Linear Distributed GaN HEMT MMIC Power Amplifier with a record OIP3/Pdc

J-S. Moon, J. Kang, D. Brown, R. Grabar, D. Wong, H. Fung, P. Chan, D. Le, C. McGuire, HRL Laboratories, Malibu, United States

MO1D-2 Power Divider with Tunable Positive and Negative Group Delays Using Parasitic Compensated PIN Diode

G. Chaudhary, P. Kim, J. Jeong, Y. Jeong, Chonbuk National University, Jeonju, Republic of Korea

09:00

MO1C-3 Experimental Characterization and Control of a Four-Way Non-Isolating Power Combiner

P. Pednekar, L. Deng, T. Barton, University of Texas at Dallas, Richardson, United States

MO1D-3 Implementation of Millimeter Wave Band DDD Radio System

K. Akahori[1], T. Taniguchi[1], M. Nagayasu [1], Y. Toriyama[1], K. Kojima[1], M. Zhang[1,2], [1]Japan Radio Co., Ltd., Tokyo, Japan, [2]Tokyo Institute of Technology, Tokyo, Japan

09:20

MO1C-4 An RF-Input Chireix Outphasing Power Amplifier

N. Faraji, T. W. Barton, University of Texas at Dallas, Richardson, United States

MO1D-4 A 24mW 5.5Gbps Dual Frequency Conversion Demodulator for Impulse-Radio with First Sidelobe

K. Kohira, N. Kitazawa, H. Ishikuro, Keio University, Yokohama, Japan

Exhibits/Wireless MicroApps/Demo

Industry Exhibits:
Monday 25 January 13:00 - 17:30
and Tuesday 26 January 09:30 - 17:00
Wireless MicroApps:
Tuesday 26 January 14:20 - 16:20
Demo Session Introductions:
Tuesday 26 January 14:00-14:15
Demo Session:
Tuesday 26 January 15:00-17:00

Power Divider with Tunable Positive and Negative Group Delays Using Parasitic Compensated PIN Diode

Girdhari Chaudhary, Phirun Kim, Junhyung Jeong and Yongchae Jeong
Division of Electronics and Information Engineering, Chonbuk National University, Korea

***Abstract* — This paper presents a design of power divider with tunable positive and negative group delays. The positive group delay can be obtained between paths 2 and 1 whereas negative group delay (NGD) between paths 3 and 1.The NGD is controlled by varying bias voltage of parasitic compensated PIN diodes. For experimental verification, power divider was designed and fabricated at center frequency of 2.14 GHz. Measurement results had a good agreement with simulation results.**

***Index Terms* — Branch line, negative group delay, transmission line, PIN diode.**

I. INTRODUCTION

Power dividers are essential blocks in microwave and millimeter systems and have been applied for power combining and splitting in various applications [1]. One of the power divider's application example is a feeding network in the beamforming of series-fed antenna arrays. However, the beamforming in series-fed antenna arrays can inherently suffer from beam-squinting, which can leads to an unwanted change in the direction and shape of radiation pattern with a frequency. This design challenge should be overcome with properly designed power distribution (power divider) network [1]. Therefore, power divider with tunable positive and negative group delays will be beneficial in such case to minimize the beam-squinting problem in series-fed antenna arrays.

In recent years, there has been an increasing amount of research on negative group delay (NGD) circuits at microwave frequencies. The group delay (GD) can be investigated by examining phase (φ) variation of forward transmitting scattering parameter. Using the differential-phase GD (τ_g) relation,

$$\tau_g = -\frac{d\varphi}{d\omega}. \qquad (1)$$

The presence of NGD is equivalent to an increasing phase (positive slope) with a frequency. Typically, the NGD phenomenon in RF circuits can be observed within a limited frequency band through the resistive signal attenuation condition [2]. Media exhibiting NGD behavior causes the output peak of a well behaved wave packet or a pulse to precede the input peak. This phenomenon does not violate a causality, since the initial transient of the pulse is still positively delayed and propagates at a speed that does not exceed the speed of light in a vacuum [2].

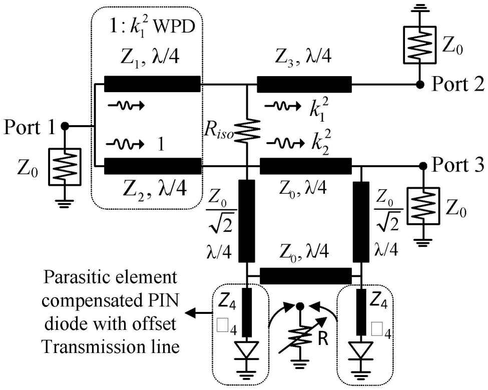


Fig. 1. Proposed structure of power divider with tunable positive and negative group delays.

Various approaches have been applied to the design of two-port active/passive microwave NGD circuits [3]-[4]. These circuits have been applied in various practical applications in communication systems, such as the realization of non-Foster reactive elements, shortening or reducing delay lines, and enhancing the efficiency of feedforward linear amplifiers [3]. However, previous works lack the GD investigation of power divider with the combination of NGDC. Therefore, research that can demonstrate the possibility of the power divider with tunable positive group delay (PGD) and NGD through different transmission paths would be promising for squint free series-fed antenna arrays.

In this paper, group delay analysis of power divider combined with NGD circuit is presented. The proposed circuit provides NGD between transmission paths 3 and 1 whereas PGD between transmission paths 2 and 1.

II. DESIGN EQUATIONS

Fig. 1 shows the proposed structure of power divider which consists of 1:k_1^2 Wilkinson power divider (WPD) and tunable branch-line NGD circuit. The WPD consists of λ/4 transmission lines with characteristic impedance of Z_1, Z_2, and Z_3. Similarly, tunable NGD circuit consists of a branch-line where direct and coupled ports are terminated with variable resistors R [3]. The characteristic impedance of transmission lines of power divider are found as (2) for zero reflection coefficient (S_{ii}=0) at f_0.

$$Z_1 = \frac{Z_0}{\sqrt{k_1^2}}\sqrt{1+\frac{1}{k_1^2}} \tag{2a}$$

$$Z_2 = Z_0\sqrt{1+k_1^2} \tag{2b}$$

$$Z_3 = \frac{Z_0}{\sqrt{k_1^2}} \tag{2c}$$

Furthermore, the S-parameters and GDs associated with different transmission paths of power divider at f_0 are determined as (3) using modified even-and odd-mode analysis [5].

$$S_{11}\big|_{f=f_0} = S_{22}\big|_{f=f_0} = S_{33}\big|_{f=f_0} = 0 \tag{3a}$$

$$S_{21}\big|_{f=f_0} = \frac{k_1}{\sqrt{1+k_1^2}} \tag{3b}$$

$$S_{31}\big|_{f=f_0} = \frac{\left|Z_0 - R\right|}{\sqrt{1+k_1^2}\left(Z_0+R\right)} \tag{3c}$$

$$\tau_{21}\big|_{f=f_0} = \frac{\left(1+k_1^2\right)\sqrt{1+k_1^2}+\left(2+k_1^2\right)\sqrt{k_1^2}}{8f_0\sqrt{k_1^2\left(1+k_1^2\right)}} \tag{3d}$$

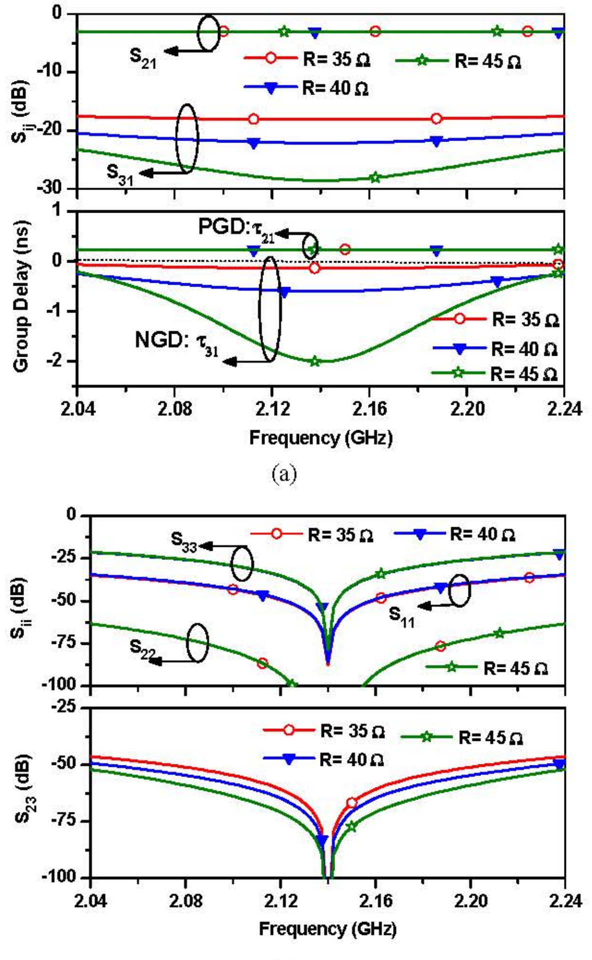
$$\tau_{31}\big|_{f=f_0} = -\frac{1}{f_0}\left\{\frac{0.6036\left(3R^2-Z_0^2\right)}{f_0\left(Z_0^2-R^2\right)} - \frac{2+k_1^2}{8\sqrt{1+k_1^2}}\right\} \tag{3e}$$

In addition, for infinite isolation (S_{23}=0) between output ports of power divider, the value of isolation resistor (R_{iso}) can be found as (4).

$$R_{\text{iso}} = Z_0\left(\frac{1+k_1^2}{k_1^2}\right) \tag{4}$$

As seen from these equations, the magnitude and GD of power divider through paths 2 and 1 depend only on k_1. Similarly, the magnitude and GD between paths 3 and 1 depend on k_1 and R. The GD between paths 2 and 1 is positive whereas that between paths 3 and 1 is negative.

For illustrative explanation of these equations, the S-parameters and GDs between different transmission paths are shown in Fig. 2 for k_1^2=1 and different values of R. As R increases toward Z_0, the GD and magnitude of S_{31} are increased towards high value. However, the magnitude and PGD between paths 2 and 1 is independent of R and only controlled by k_1. The input and output ports are matched with reference impedance at f_0 as shown in Fig. 2(b). Similarly, isolation between output ports are infinite at f_0 for different values of R.



(a)

(b)

Fig. 2. Synthesized results using ideal circuit parameters and k_1^2=1: (a) group delay/magnitude, (b) return loss/isolation characteristics.

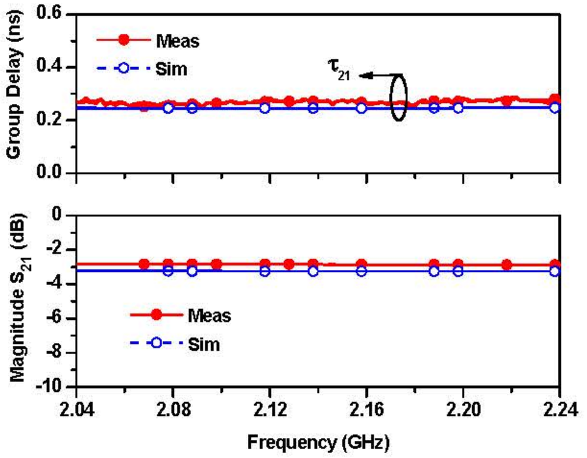


Fig. 3. Simulated and measured group delay/magnitude between paths 2 and 1 with k_1^2=1.

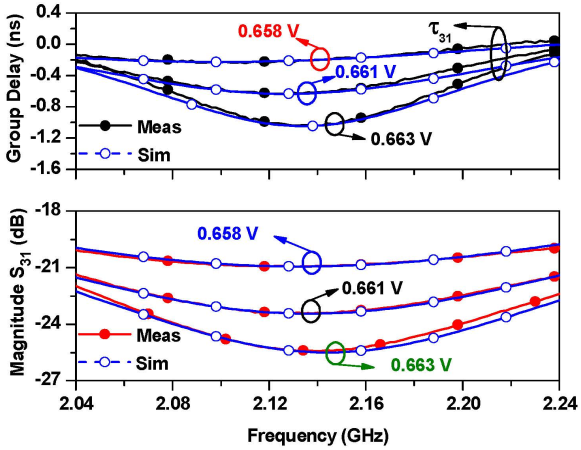


Fig. 4. Simulated and measured group delay/magnitude between paths 3 and 1 with k_1^2=1.

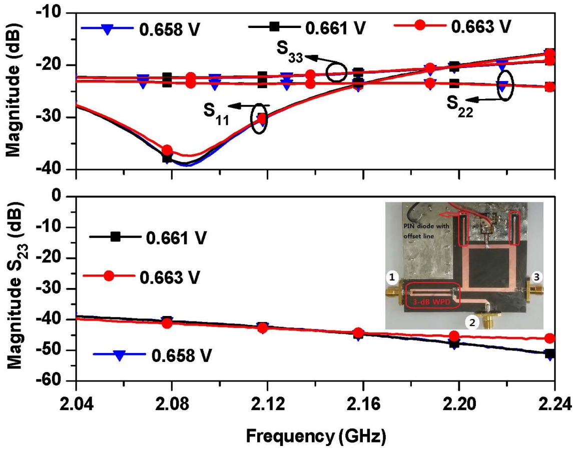


Fig. 5. Simulated and measured return losses and isolation characteristics with k_1^2=1.

III. SIMULATION AND EXPERIMENT RESULTS

For experimental verification, we designed and fabricated the proposed power divider with k_1^2=1 at f_0 of 2.14 GHz. The circuit was fabricated on a Rogers RT/Duriod 5880 substrate with a dielectric constant (ε_r) of 2.2 and a thickness (h) of 31 mils. The circuit was simulated and optimized using ANSYS HFSS 2014 and Advanced Design System (ADS) 2013.

In this work, the variable resistors are implemented with PIN diodes HSMP-4810 from Avago which functions as a current-controlled variable resistor at microwave frequencies. To compensate the parasitic components of the PIN diode such that their input impedance is purely resistive, the PIN diode is terminated in offset transmission line (TL) with electrical length of θ_1 and characteristic impedance Z_4. The design equations are presented in [6]. The characteristic impedance and electrical length of TL are given as 82 Ω and 72.2° at f_0 = 2.14 GHz.

The simulated and measured the magnitudes and GDs are shown in Fig. 3 and 4. The measured $|S_{21}|$ and τ_{21} between paths 2 and 1 are remained almost constant at value of -2.96 dB and 0.27 ns at 2.14 GHz, respectively. Similarly, the measured values of $|S_{31}|$ between paths 3 and 1 are varied from -20.90 dB to -25.45 dB with GDs variations of -0.2 ns to -1.04 ns at 2.14 GHz. Therefore, the measured power division ratio is varied from 17.94 dB to 22.49 dB. The GD and power division ration can be varied further. However, NGD and magnitude band width will be decreased. Therefore, there is a trade-off between GD and bandwidth. From Fig. 5, the measured $|S_{11}|$, $|S_{22}|$, and $|S_{33}|$ are -24.73 dB, -20.58 dB, and -20.62 dB, respectively. The measured isolation ($|S_{23}|$) at f_0 is -42.18 dB. A photograph of fabricated circuit is shown in Fig. 5.

IV. CONCLUSION

In this paper, a power divider with tunable positive and negative group delays is proposed and fabricated. Both theoretical and experimental results have been presented for verification. The negative group delay between paths 3 and 1 was controlled by varying bias voltage of PIN diodes. In addition, the proposed power divider is promising for application as feed network in series fed antenna arrays for minimizing beam-squint.

REFERENCES

[1] H. Mirzaei and G. V. Eleftheriades, “Arbitrary-angle squint-free beamforming in series-fed antenna arrays using non-Foster elements synthesized by negative group delay networks,” *IEEE Trans. Antennas and Propagation,* vol. 63, no. 5, pp. 1997-2010, May, 2015.

[2] M. W. Mitchell and R. Y. Chiao, “Causality and negative group delays in simple bandpass amplifier,” *Am. J. Physics*, vol. 70, no. 11, pp. 1117-1121, Nov. 2002.

[3] G. Chaudhary, Y. Jeong, and J. Im, “A design of reconfigurable negative group delay circuit without external resonators,” *IEEE Antennas and Wireless Propagation Letters*, vol. 14, pp. 883-886, 2015.

[4] H. Choi, Y. Jeong, C. D. Kim, and J. S. Kenney, “Efficiency enhancement of feedforward amplifiers by employing a negative group delay circuit,” *IEEE Trans. Microw. Theory Tech.*, vol. 58, no. 5, pp. 1116-1125, May 2010.

[5] H. R. Ahn, Asymmetric passive components in Microwave Integrated Circuits, New York, NY, USA: Wiley, 2006.

[6] J. Jeong, S. Park, G. Chaudhary, and Y. Jeong, "Design of tunable negative group delay circuit for communication systems," *Proc. of IEEE Radio-Frequency Integrated Tech.*, pp. 59-61, Nov. 2012.