Quad-Band NGD Investigation on Crossed Resonator Interconnect Structure

Taochen Gu, Jiahui Chen, Blaise Ravelo, *Member, IEEE*, Fayu Wan, *Senior Member, IEEE*, Vladimir Mordachev, *Member, IEEE*, and Qizheng Ji

***Abstract*—This brief explains why the coupling between crossed interconnect structure and straight I-lines of printed circuit board (PCB) presents bandpass (BP) negative group delay (NGD) behavior. The NGD effect is investigated with crossed resonator innovative microstrip equivalent topology. As proof of concept (POC), the influences of crossed resonator circuit physical variables on the BP-NGD behavior are illustrated by parametric study. The cross-coupled microstrip circuit POC BP-NGD responses is validated with quad-band NGD behavior. A very good agreement between calculations, simulations and experimentations state results of NGD center frequency-NGD value, (1.541-GHz, −1.84-ns), (2.397-GHz, −1.6-ns), (3.379-GHz, −1.38-ns), and (4.164-GHz, −0.91-ns) representing the 1st, 2nd, 3rd and 4th NGD band, respectively. The studied design has notable advantages in term of NGD application integration in the multi-band transceiver system simplicity and size reduction.**

***Index Terms*—Design method, negative group delay (NGD), bandpass NGD topology, crossed resonator interconnect structure, quad-band (4B) NGD microstrip circuit.**

I. Introduction

RECENT studies [1]–[10] state that negative group delay (NGD) circuits are potentially useful to improve electronic and communication component performances. A broadband switch-less bi-directional amplifier was designed with NGD matching circuits [3]. Compensation [4]–[6] and equalization [7]–[8] techniques using NGD circuit were proposed. The NGD equalization extension enables to develop resonance reduction technique [9]. Innovative negative capacitance using a passive non-Foster NGD circuit was introduced [10]. Despite tentative applications, compared to classical communication engineering function, the NGD design engineering remains so far, an unfamiliar concept for electronic engineers. Therefore, further didactical research work on NGD effect familiarization and circuit engineering is necessary. Indeed, the NGD effect was inspired from negative group velocity media [11] which leads to the elaboration of typical absorptive resonant NGD circuit [12]–[13]. The NGD signature in time-domain can be identified by the possibility to propagate smooth signal in time-advance without violating the causality [13]–[15]. Since the last two decades, some research works about the NGD circuit topology exploration and designing low loss and compact NGD topologies were performed [16]–[17]. As results, it was found out that there are diverse topologies [11]–[17] of NGD circuits. For the better familiarization about the NGD circuit engineering, a fundamental NGD circuit theory inspired from filter one was initiated [18]. The concept of bandpass (BP) type NGD circuit is the most developed ones in the area of microwave design engineering [11]–[13],[16]–[24]. One of BP-NGD topology best trade off in terms of NGD specifications (value, center frequency, bandwidth (BW), loss and matching) can be achieved with microstrip coupled lines (CLs) [19]–[24]. Remarkable research work on CL-based BP-NGD design including dual-band circuits [22]–[24] was performed few years ago. However, few research works were made on multiband ones which is particularly interesting for wireless application [1]–[2]. The present work novelty is on the quad-band (4B) BP-NGD design and experimentation of crossed resonator interconnect line (IL) structure.

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Taochen Gu, Jiahui Chen, Blaise Ravelo, and Fayu Wan are with the School of Electronic and Information Engineering, Nanjing University of Information Science and Technology, Nanjing 210044, China (e-mail: fayu.wan@nuist.edu.cn).

Vladimir Mordachev is with the Research and Development Laboratory of Electromagnetic Compatibility, Research and Development Department, Belarusian State University of Informatics and Radioelectronics, 220013 Minsk, Belarus.

Qizheng Ji is with the National Key Laboratory on Electromagnetic Environment Effects, Army Engineering University of PLA (Shijiazhuang Campus), Shijiazhuang 050003, China.

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II. Description of the 4B-NGD Circuit With Crossed Resonator Interconnect Structure

The present section describes the 4B-NGD design method of the cross resonator based microstrip circuit under study.

A. Topological Investigation

The 4B-NGD distributed topology is comprised of interconnect CL combined to resonator structure. Fig. 1(a) depicts the two-port passive topology. The cross resonator consists of a common uniform impedance resonator (UIR) with physical parameters l_3, l_4 and l_7. The short- l_5 and open-end transmission lines (TLs) l_6 are connected in parallel on the UIR. θ is the length of the coupler or the transmission, and "g" is the coupler gap. A portion of UIR(l_3) is coupled to IL length L. Fig. 1(b) shows the crossed resonator coupled to IL L forms a two-wire CL structure