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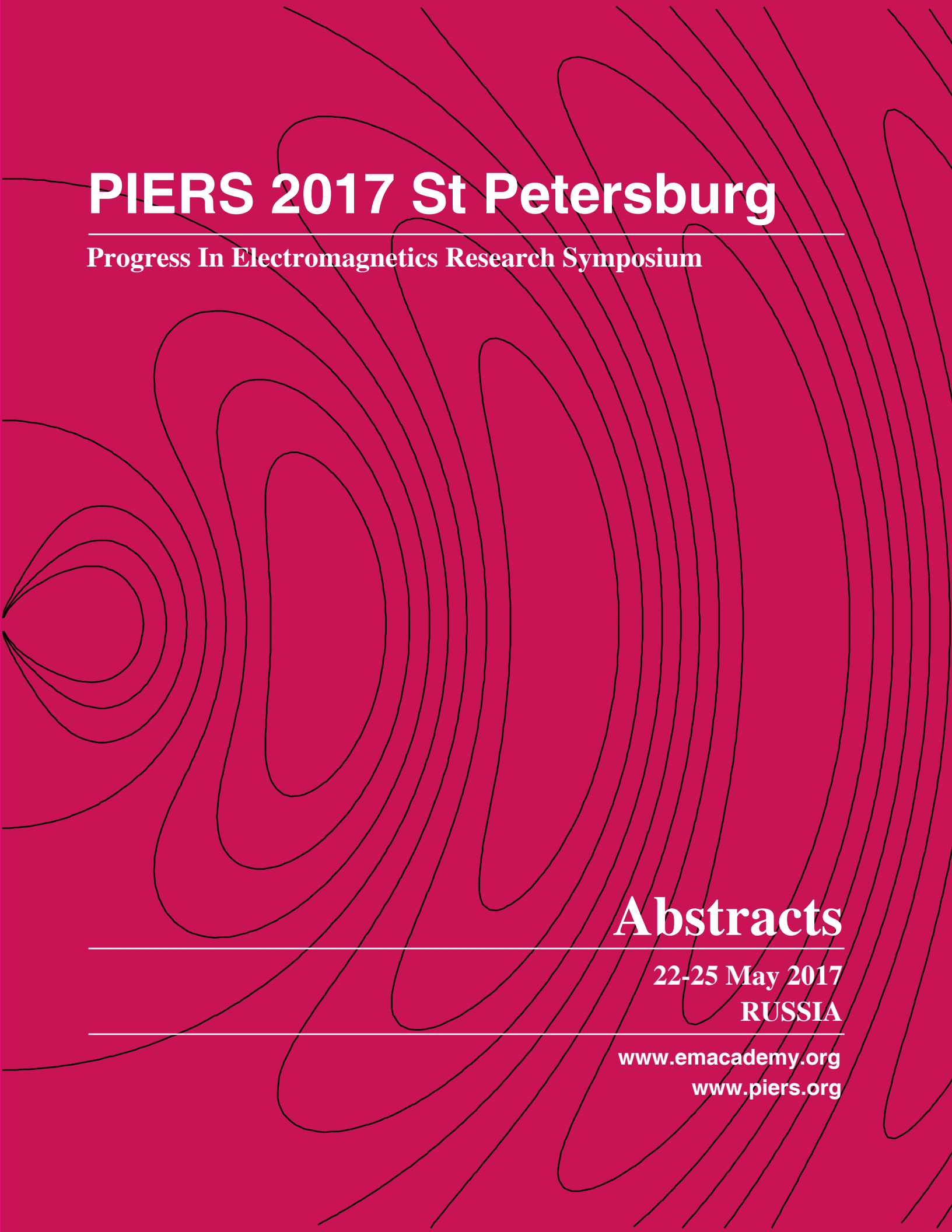

Abstracts

22-25 May 2017
RUSSIA

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Session 4A7
Microwave and Millimeter Wave Circuits and Devices, CAD 1

A Design of 180° Coupler with Predefined Negative Group Delay Characteristics

Girdhari Chaudhary[1], **Boram An**[1], **Phirun Kim**[1], **Jongsik Lim**[2], **and Yongchae Jeong**[1]

[1]Division of Electronics and Information Engineering, Chonbuk National University, Republic of Korea
[2]Department of Electrical Engineering, Soonchunhyang University, Republic of Korea

Abstract— Recently, there has been an increasing amount of research on negative group delay (NGD) circuits at microwave frequencies. In a medium of refractive index $n(\omega)$, the dispersion relation [1] can be written as (1)

$$k = \frac{\omega n}{c} \tag{1}$$

where ω, k, and c respectively denote angular frequency, wave number, and the speed of light, respectively. The group velocity (v_g), known as the envelope speed of the signal [1], can be given as (2).

$$v_g = \frac{c}{n + \omega \mathrm{Re}\,(dn/d\omega)} \tag{2}$$

From (1) and (2), it is inferred that if refractive index n and its derivative with respect to ω are negative (i.e., $dn/d\omega < 0$), the v_g and, consequently, the group delay (GD) can become negative. This occurs in media with signal attenuation (SA), whereby an 'anomalous' wave propagation effect can occur [1]. Typically, the NGD phenomenon in RF circuits can be observed within the limited frequency band through the SA condition.

The physical NGD phenomenon implies a negative delay (i.e., a time advancement). This interesting characteristic of NGD circuit has been applied to various practical applications in communication systems, such as shortening or reducing delay lines, enhancing the efficiency of feedforward linear amplifiers, enhancing the bandwidth of feedback linear amplifiers, and minimizing beam-squint in phased array antenna systems [2]. Recently, new and interesting applications of NGD circuits have been reported in the realization of non-Foster reactive elements, such as negative capacitances or inductances [3].

Various approaches have been applied to designing two-port active/passive microwave NGD circuitss using RLC resonators [4]. To overcome the limited availability problem of lumped elements in radio and microwave frequencies, NGD circuits that use distributed elements have also been presented in several works [5]. However, research on designing a coupler with predefined NGD characteristics is lacking. Research that can demonstrate the possibility of a coupler design with these characteristics through different transmission paths would be promising.

In this paper, we present theoretical and experimental investigations of a 180° coupler with predefined NGD and an arbitrary power division ratio. From the theoretical analysis, the NGD characteristics can be obtained through various transmission paths independently of the power division ratio. The power division ratio is controlled by only the characteristic impedance of transmission lines. Ideal port isolation and return loss characteristics are obtained at a center frequency for any arbitrary power division ratio.

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