ISSN 0735-2727, Radioelectronics and Communications Systems, 2014, Vol. 57, No. 12, pp. 521–530. © Allerton Press, Inc., 2014.
Original Russian Text © A.A. Kirilenko, N.G. Kolmakova, A.O. Perov, S.A. Prikolotin, V.N. Derkach, 2014, published in Izv. Vyssh. Uchebn. Zaved., Radioelektron., 2014, Vol. 57, No. 12, pp. 3–15.

Natural Oscillations Providing 90° Polarization Plane Rotation by Planar Chiral Double-Slot Irises

A. A. Kirilenko[1*], N. G. Kolmakova[2], A. O. Perov[1], S. A. Prikolotin[1], V. N. Derkach[1]**

[1] *Usikov Institute of Radiophysics and Electronics of the National Academy of Sciences of Ukraine, Kharkiv, Ukraine*

[2] *St. Petersburg State Polytechnical University, St. Petersburg, Russia*
**e-mail: kirilenko@ire.kharkov.ua*
***e-mail: kolmakova.nataliya@gmail.com*

Received in final form July 21, 2014

Abstract—The common origin of the "enhanced transmission" through small holes and polarization plane rotation ("optical activity") resonances peculiar for a pair of conjugated planar chiral irises is demonstrated. The eigenoscillation spectra are studied extensively from the "aperture" eigenoscillations of plane junctions responsible for the "enhanced transmission" through the planar chiral iris up to the eigenoscillations of "dihedral" symmetry formed in a composite double slot planar chiral iris. Their excitation results in polarization plane rotation of the dominant mode in a square waveguide. A new compact unit for TE_{01} to TE_{10} conversion operating within 5–10% frequency band is proposed and validated experimentally. All conclusions are valid for various types of metasurfaces based on the "fish-net" gratings.

DOI: 10.3103/S0735272714120012

1. INTRODUCTION

The ubiquity of powerful computers and commercial software based on the FE or FDTD methods has increased greatly the publications devoted to study of sophisticated 3D configurations for possible innovative applications. For example, the analysis of objects, providing large angles of polarization plane rotation due to electromagnetic interaction by fringing fields [1] can be found in [2–6]. They are mainly based on planar chiral gratings of metal patches: two adjacent layers of mutually turned crosses [3], simple [4] or "polypetalous" [5] gammadions, and tetrachoric structures of split rings [6] where the "geometry conjugation" of adjacent complicated gratings provides large angles of polarization plane rotation.

General approach to synthesis of polarization transformers has been proposed in [7]. It is based on usage of volumetric electrically small dipolar particles. Owing to the ability to design required polarizability of separate 3D cells, a grating of them can provide either polarization plane rotation or different reflecting properties for right-handed or left-handed circular polarizations.

Described previously, cases of patch type [1–6] and "fishnet" type gratings considered in [8] prompt us to another general idea that is based on 2D chiral objects interacting by fringing fields. It is quite sufficient to take two conjugated, closely spaced, resonating planar chiral objects that have C_4 or even C_2 rotational symmetry to obtain close to perfect transmission into the mode with a rotated polarization plane.

The first important point of our idea is that the slot-based ("fishnet" type) structures turn out preferable to "patch" type ones as separate components possess resonant transmission properties. The second important point is that such a composite unit is characterized by a pair of eigenoscillations providing corresponding points of good matching. They are perfect matching points in C_4 case and close to perfect ones in C_2 case. Moreover, gap tuning makes it possible to obtain wide-band "two-hump" frequency response. This fact has not been highlighted before, because dependencies on a gap have not been studied at large.

The suggested approach to rotator design has been validated on a waveguide structure with C_4 symmetry [9, 10]. It consists of two conjugated planar chiral irises with quadruples of rectangular slots that provide evident resonance properties. Some summarizing conclusions were published in [11]. The experimental results related to "fish-net" type grating with similar cells were briefly described in report [12]. The common