A Simple Broadband FSS Polarizer

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***Abstract*—This work presents the design and performance analysis of a simple linear to circular polarization converter made of cascaded periodic slotted surfaces. The final structure, obtained after an optimization procedure, consists of three layers of identical shape. The analysis is performed via a spectral domain method of moment and the inter-sheet coupling is taken into account via a multimode equivalent transmission line model. Despite the simple geometry, the device exhibits a 3dB axial ratio bandwidth of 13% and a -10dB reflection coefficient bandwidth of 10%.**

Index Terms— frequency selective surfaces, transmission polarizer, periodic surfaces, circular polarization.

I. INTRODUCTION

IN telecommunication engineering the use of circularly polarized electromagnetic waves gives some advantages and it is sometimes a simple way for providing solutions to tricky tasks. Well-known radar applications are concerned with the interaction of the electromagnetic wave with water drops in the atmosphere. Water drops, in fact, reflect a circularly polarized wave in the opposite sense of the transmission, thus, making it possible to separate the target effect from the weather clutter. This provides a significant advantage for both meteorological studies and decluttering techniques [1]. Furthermore, in many telecommunication systems involving satellite-earth links, due to the ionospheric Faraday effect, a linearly polarized wave assumes unpredictable orientation, thus producing a polarization mismatch at the receiving antenna, with consequent loss of gain in the link budget [2]. The use of a circularly polarized signal is a straightforward manner to face the described issues. Therefore, it is sometimes necessary to use circularly polarized high-gain antennas, especially in satellite systems. If the radiating system consists of a planar array, a quite natural solution for obtaining circular polarization (CP) consists in the use of a planar polarizer to be placed on top of the linearly polarized antenna system. This kind of solution may also be used to obtain a reconfigurable system, mechanically or electronically switching from linear polarization (LP) to CP, without any modification of the beam forming network. In fact, although it is possible to manufacture a single reconfigurable LP-CP patch antenna by using a set of PIN diodes [3], it would be tricky and expensive to include these elements in a large array. Therefore, putting a planar polarizer on top of an array is still a nice solution to face the problem.

Planar polarizers are generally realized by using frequency selective surfaces (FSS). One of the first FSS-type structures to perform LP-CP conversion was realized in [4] as a cascade of three sheets consisting of arrays of combined wires and rectangles. In this configuration the wires act as an equivalent shunt inductance for the electric field component parallel to them, and the rectangular patches act as an equivalent shunt capacitance for both the electric field components. This effect can be tailored by adjusting the diameter of the wires and the dimensions of the rectangles. Cascading more sheets, the required 90° phase shift between the two orthogonal field components can be obtained along with impedance matching. This concept was improved and refined in the design of a *meander-line* polarizer, first presented in [5] and subsequently used also at millimeter waves [6] and in more complex antenna geometries [7]. Alternative FSS geometries have been recently analyzed in [8].

The challenging issue in FSS-type polarizers is represented by the operational bandwidth. We propose here a polarizer realized by cascading layers of slot FSS, with the objective of enlarging the operational bandwidth. For simplicity, we limit the example here to three layers, understood that the design process can be extended to a larger number of layers.

II. DESIGN AND PERFORMANCES

The designed polarizer is based on the use of slot-type FSS, in order to combine the polarization conversion effect and the pass-band characteristic typical of these structures. The FSS is freestanding in order to limit the insertion losses.

Among the many possible slot geometries, we have focused our attention on the "T" configuration shown in Fig. 1. This particular geometry can be modeled as two weakly coupled magnetic dipoles, each of which interacts with one of the two orthogonal field components. It is assumed that the incident field impinges normally to the structure, and it is linearly polarized with the electric field lying rotated by an angle of 45° with respect to the x-axis. The good property of this geometry is that, although the two slots are joined, thus allowing for a compact unit cell, their resonance can be set almost independently as if they were physically separated.

The characterization of the electromagnetic response of the single planar periodic surface and the final optimization of the geometrical parameters have been performed via the algorithm described in [9], which is based on an equivalent transmission line model. In order to accurately represent the inter-layer coupling, the higher-order Floquet modes interactions have been taken into account by using the *accessible modes* concept [10]. Due to this fact, the equivalent network model comprises a multimode transmission line, with N_A accessible modes for the TE polarization and N_A accessible modes for the TM polarization.

The designed impedance matched polarizer consists of 3 identical periodic layers whose unit cell is described by the parameters reported in Table I. The phase difference between the transmitted E_y and E_x field components is well stable around -90°, thus indicating that the condition for right-hand CP has been obtained in a pretty large frequency band. The performances of the device are shown in terms of transmitted power (Fig. 2) and axial ratio (Fig. 3). From the analysis of these two parameters it can be seen that the 3dB axial ratio bandwidth and the -10dB reflection coefficient bandwidth are of 13% and of 10%, respectively.

TABLE I
GEOMETRICAL PARAMETERS NORMALIZED TO FREE SPACE WORKING WAVELENGTH FOR THE THREE LAYER POLARIZER

$d_x = d_y = 0.474$	$l_h = 0.336$	$w_h = 0.030$
$d_z = 0.182$	$l_v = 0.462$	$w_v = 0.030$

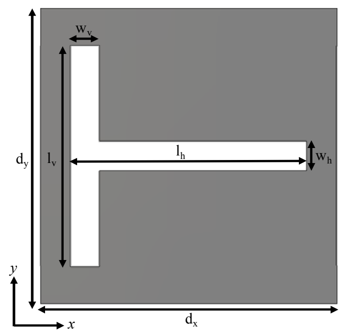

Figure. 1. Geometry of the unit cell for each sheet of the multilayer circular polarizer: d_x and d_y are the periods along *x* and *y*, respectively, l_h and l_v are the horizontal and vertical slot lengths, respectively, and w_h and w_v are the horizontal and vertical slot widths, respectively.

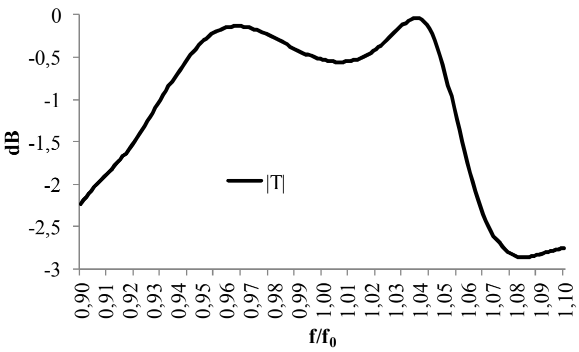

Figure. 2. Power transmission coefficient for the three layer polarizer in case of normal incidence ($\theta = 0°, \varphi = 45°$).

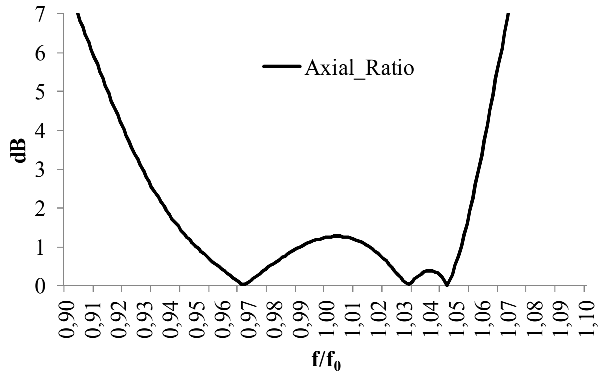

Figure. 3. Axial ratio for the three layer polarizer in case of normal incidence($\theta = 0°, \varphi = 45°$).

III. CONCLUSION

The design of a linear to circular polarization converter realized by three closely packed slot FSS has been presented. The layers are identical and have been designed to operate without any dielectric slab. Numerical results show quite good performances in terms of axial ratio and reflection bandwidth. A wider bandwidth may be achieved by using more layers.

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