

Angular-stable polarization rotator

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Angular-Stable Polarization Rotator

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Abstract—A new polarization rotator based on a recently proposed 3-D frequency selective structure (FSS) is designed. The rotation is an added function to the band-reject FSS, which is built using an array of parallel plate waveguides. The device exploits an L-shaped slot to generate a 90° rotated E-field component at the output. An example is designed here, operating at 10 GHz, with a half-power (3-dB) fractional bandwidth of 2.7% for the transmission coefficient of the rotated field. The insertion loss is 1.3 dB at the resonant frequency. The proposed rotator exhibits good stability over a large range of oblique incidence. The operating principle of the L-slot is explained, along with an illustration of the field behavior, and the design details are briefly discussed.

I. INTRODUCTION

Frequency selective structures (FSS) have become a subject of extensive research recently for their attractive free-space filtering functions required in many applications. Conventional designs involve 2D structures using dielectric substrates where different geometrical shapes for slots and copper strips are etched to realize the capacitive and inductive elements necessary for the filtering function. One drawback of such periodic structures is that their performance stability is subject to disruption under large oblique incidence angles.

Passive polarization rotation/conversion devices are of crucial importance in many applications, especially in association with antennas [1]. Recently, some polarization manipulation structures have been realized based on the abovementioned conventional 2-D frequency selective surface designs [2], [3]. However, such designs are less tolerant to large oblique incidence angles as frequency shifting can arise, limiting the stability over the operation range.

Given the above, a new polarization rotator is developed, based on an array of parallel-plate waveguides (PPWs), a slightly modified version of the FSS design presented in [4], with an etched slot for the polarization rotation to function. The presented design operates in the X-band, exhibiting a stable operation against large variations of incidence angles, besides having a relatively smaller unit-cell size.

II. DESCRIPTION OF THE STRUCTURE

A. Parallel Plate Waveguide

The design follows the principle developed in [4] to realize a dual-mode resonator to achieve band-rejection. The dual-mode resonator is slightly modified for simpler design and for accommodating the slot, by extending the strip as wide as the ground, realizing a simple PPW. An equivalent circuit

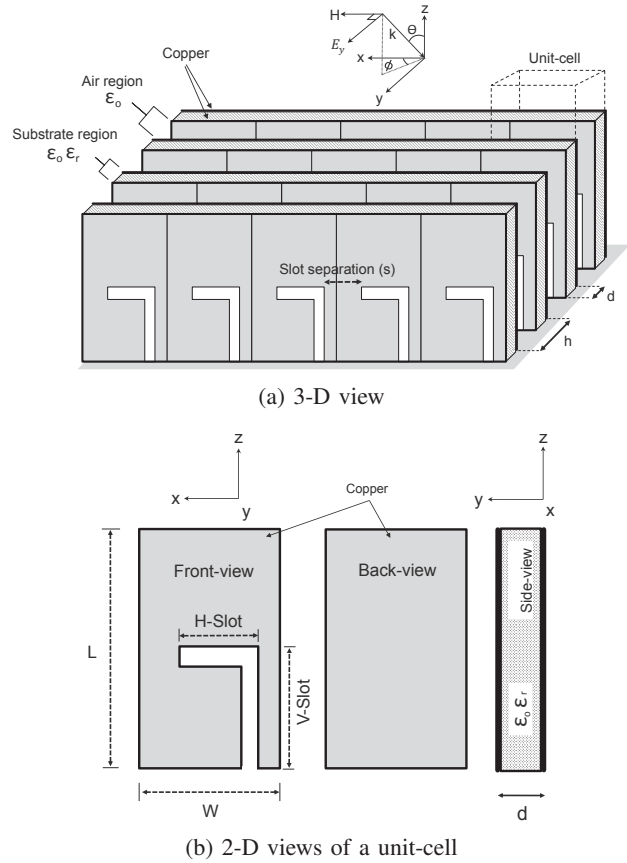


Fig. 1: Geometry of the proposed polarization rotator.

model can be established and the circuit element values can be calculated in a similar way to that presented in [5]. The structure is shown in Fig. 1. Two fundamental TEM modes are excited between two parallel plates: one passes through the substrate region, another through the air region. They both realize the band-reject performance, which basically restricts the transmission of the E-field component incident in a perpendicular fashion to the (x-y) plane of the PPW array. In order for the rotator to operate in the X-band, the following PPW dimensions are chosen: $L = 6.8$ mm, $W = 4.1$ mm, $h = 2.02$ mm, $d = 1.524$ mm, $\epsilon_r = 11.2$. The largest dimension of the structure (L) is less than a quarter of the free-space wavelength at 10 GHz.

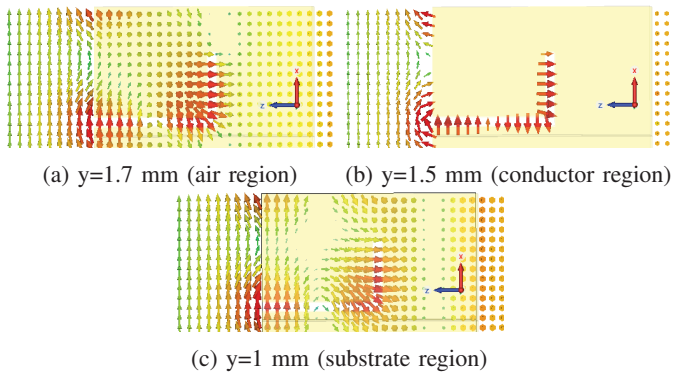


Fig. 2: Distribution of the E-field in the x-z plane for different regions of the polarization rotator.

B. L-Slot

The L-shaped slot is etched on one of the two plates, as shown in Fig. 1. The purpose is to rotate the field that is coupled to L-slot's horizontal part (H-Slot) by 90 degrees, so that it is later radiated at the open end of L-slot's vertical part (V-Slot). The polarization rotation effect is shown in Fig. 2, where the E-field behavior is depicted in the air, substrate and conductor planes. The slot introduces a vertical E-field transmission zero at 10 GHz, then transforms it into a horizontal E-field transmission pole at the given frequency.

III. RESULTS AND DISCUSSIONS

The resonant frequency of the rotated E-field component is affected by multiple parameters, mainly H-Slot, V-Slot, s , ϵ_r , d , and $h - d$ (air gap). Since ϵ_r , d , and $h - d$ have a direct effect on the band-rejection performance of the FSS as part of its design parameters, they are not considered here for the polarization rotator. Only H-Slot, V-Slot, and s are considered after realizing the desired band-stop performance. The optimized values for the L-slot dimensions are chosen as: H-Slot = 3.5 mm, V-Slot = 0.5 mm, $s = 4.1$ mm. Adding V-Slot and H-Slot yields almost $0.5\lambda_g$ (guided wavelength) at 10 GHz, with ϵ_{eff} slightly lower than ϵ_r because of the L-slot's existence. The V-Slot is kept open at its end to re-radiate the rotated field.

The simulated response is shown in Fig. 3. The insertion loss is 1.3 dB at 10 GHz with a 3-dB fractional bandwidth of 2.7%. A slight shift in frequency can be observed when comparing these two cases with and without the L-slot. This can be attributed to the slight change in ϵ_{eff} of the substrate-filled PPW since the etched slot exposes an area of the PPW to the air-filled region, lowering the overall ϵ_{eff} as well as the coupling between the plates. The performance against a wide range of incidence angles is shown in Fig. 4. The transmission pole is stable under 25° incidence. Slight shifting by around +0.03 GHz starts at 50° , yielding a 1.6 dB insertion loss for the rotated E-field component at 10 GHz, indicating a good tolerance toward a large variation of incidence angles.

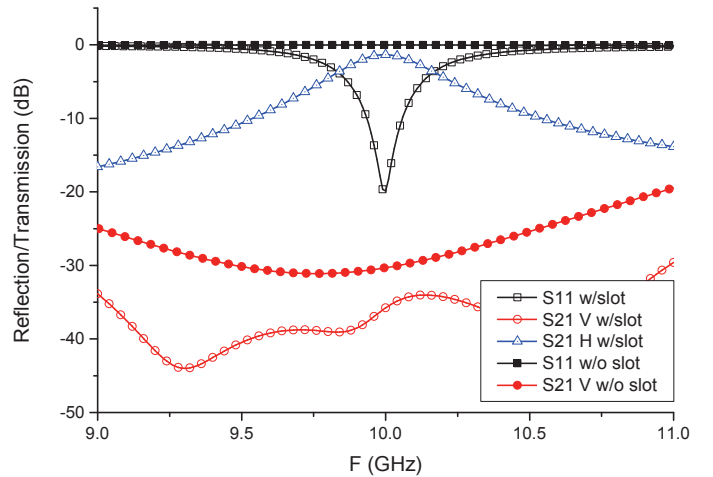


Fig. 3: Simulated reflection and transmission coefficients of the polarization rotator with and without the L-slot. V and H are the vertical and horizontal E-field components, respectively.

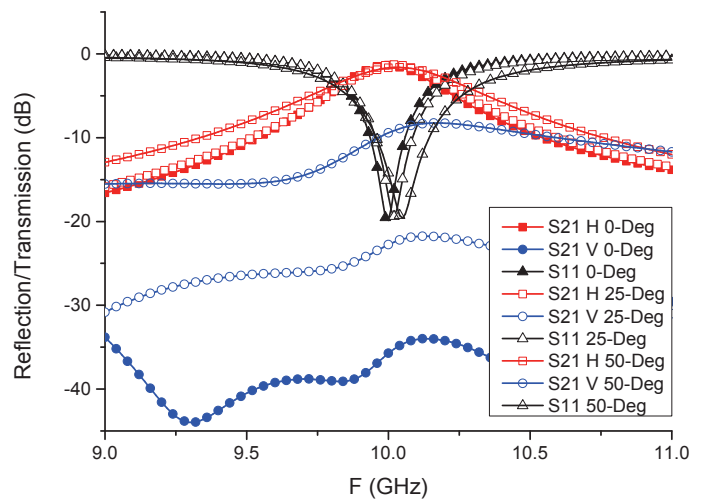


Fig. 4: Simulated reflection and transmission coefficients of the polarization rotator under different incidence angles.

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