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► **To cite this version:**

Reda Madi, Antonio Clemente, Ronan Sauleau. A Switchable Linear to Circular Polarization Converter Using PIN Diodes. 2021 International Symposium on Antennas and Propagation, Oct 2021, Taipei, Taiwan. hal-03515124

HAL Id: hal-03515124

<https://hal.science/hal-03515124>

Submitted on 6 Jan 2022

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A Switchable Linear to Circular Polarization Converter Using PIN Diodes

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Abstract - In this paper, we present a method to design a switchable polarizer using p-i-n diodes. An antenna-filter-antenna architecture with four metal layers (receiving and transmitting radiating elements, ground plane, and bias lines) is implemented to convert an impinging linearly-polarized electromagnetic wave to a circularly-polarized one. Furthermore, by controlling opportunely the bias current flowing on the two p-i-n diodes flip chipped on the transmitting radiating element, the transmission wave can be switched to either left-handed circular polarization (LHCP) or right-handed circular polarization (RHCP). Full-wave electromagnetic simulations of a single element show a transmission loss < 0.8 dB for both polarization (LHCP/RHCP) and 180° phase difference in the frequency band (27 - 31 GHz).

Keywords — Polarizer, circular polarization, polarization converter, p-i-n diodes, EM-wave manipulation, mm-wave applications.

I. INTRODUCTION

Nowadays broadband satellite communications (SatCom) at K-/Ka-band are experiencing a growing interest. In this applicative context, one of the most important antenna requirement is the capability to radiate a circularly-polarized beam. Indeed, circular polarization (CP) is used to mitigate Faraday rotation effects, multi-path fading, and interferences caused by environmental factors, such as rain or fog. Furthermore, CP switch is also essential for terminal antennas to handle with the handover from one cell to another one.

P-i-n diodes based reconfigurable transmitarray antennas [1],[2], with electronic beam steering and CP agility, have been proposed recently as an energy-efficient alternative to classical phased arrays. In order to simplify the antenna architecture and limit the number of switches, these transmitarrays use a random distribution of vertical and horizontal polarized unit-cells to generate the CP. Even if this strategy allows to achieve extremely low axial ratio (< 1 dB), a gain reduction of 3 dB is obtained due to the particular sequential rotation schemes used to generate CP. An alternative solution to generate CP agility without sequential rotation losses is the combination of a linearly-polarized antenna with a switchable linear-to-circular polarization converter. Several passive [3]-[5] and reconfigurable [6],[7] polarization converters have been proposed in the literature.

In this contribution, a reconfigurable linear-to-circular polarization converter is proposed. Compared to the state of

the art, the proposed architecture uses only two p-i-n diodes and a single bias line to generate the polarization switch.

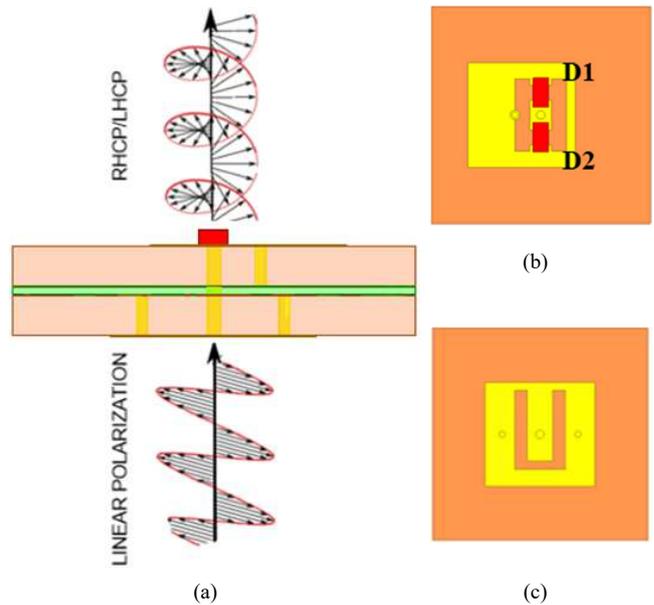


Fig. 1. Circular polarizer unit-cell (a) side view, (b) top view and (c) bottom view.

II. UNIT-CELL DESIGN

The unit-cell of the proposed polarization converter operates at Ka-band (27 – 31 GHz). Its aperture size equals 5.1×5.1 mm² (i.e. $\lambda_0/2 \times \lambda_0/2$, where λ_0 is the wavelength in free space at 29.4 GHz). The selected stack-up is shown in Fig. 1(a). It consists of two identical substrates (Astra MT77, thickness 508 μ m, $\epsilon_r = 3$ and $\tan\delta = 0.0017$), a bonding film and four metal layers. The receiving (Rx) layer is composed of a linearly-polarized square patch loaded by a U-shaped slot (Fig. 1(c)). At the transmitting layer (Tx), an active patch loaded by an O-shaped slot and two p-i-n diodes (indicated as D1, D2 in Fig. 1(b)) is design. An asymmetric excitation is selected to generate CP. The two patches are connected with a metallized via hole placed at the center of the unit-cell. A ground plane and the bias line are realized on the inner layers. Metallized vias are used to connect the Rx and the Tx patch antennas to the ground plane and the bias line, respectively.

As presented in Table I, the linear-to-circular polarizer converter operates in RHCP when D1 is ON and D2 is OFF.

LHCP is achieved when D1 is OFF and D2 is ON in the frequency. The diodes states are controlled by using a negative or a positive current of 10 mA.

TABLE I TRUTH TABLE OF THE PROPOSED POLARIZATION CONVERTER

Diode state		Polarization
D1	D2	
ON	OFF	RHCP
OFF	ON	LHCP

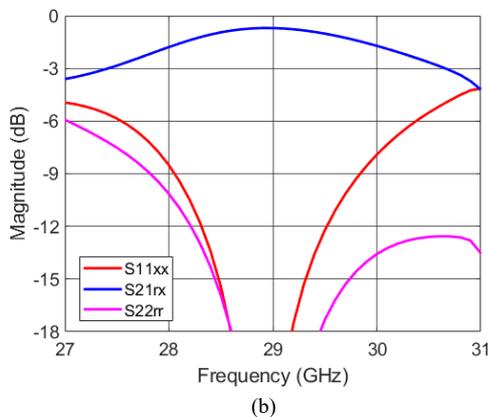
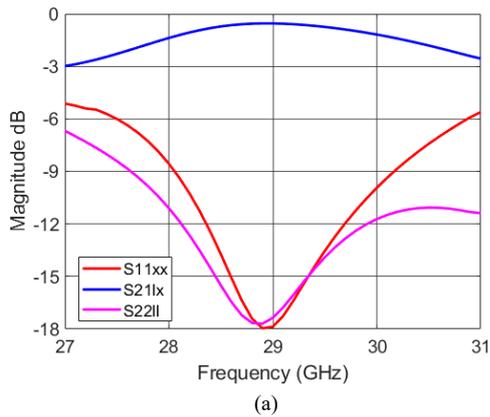


Fig. 2. Amplitude of the transmission and the reflection coefficients for the (a) LHCP and the (b) RHCP.

III. SIMULATION RESULTS

The proposed unit-cell has been simulated and optimized using the commercial software Ansys HFSS with periodic boundary conditions and Floquet port excitations. The p-i-n diode are modeled as in [1],[2]. The simulated magnitude of the reflection and the transmission coefficients of the polarizer and the transmission phase are shown in Fig. 2 and Fig. 3, respectively. It is observed that by changing the state of the diode we can switch from left handed to right handed circular polarization, Figs. 2(a)-(b), respectively. Very similar results are obtained for the two states. At 29 GHz, the unit-cell exhibits a minimum insertion loss of 0.70 and 0.55 dB for the

LHCP and RHCP, respectively. The 3-dB relative transmission bandwidth is equal to 15.2% and 11.4% for the LHCP and the RHCP, respectively.

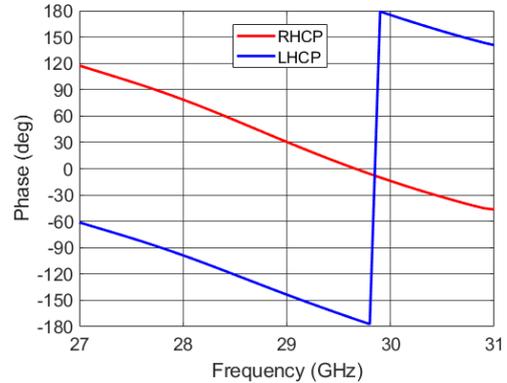


Fig. 3. Transmission phase for the RHCP and the LHCP.

IV. CONCLUSION

In this paper, we presented a polarizer that converts a linearly polarized wave to a circularly polarized one. It operates at Ka-band and can be electronically switched to LHCP or RHCP by changing the states of the p-i-n diode. The proposed UC exhibits 15.17% and 11.38% 3-dB transmission bandwidth at 29 GHz for the LHCP and the RHCP, respectively.

ACKNOWLEDGMENT

This work was partly supported by the National Research Agency (ANR) through the project ANR-ASTRID ArtiKa under grant ANR-20-ASTR-0014-01.

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