Recent progress of developing Ka-Band Circular Polarizers

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Abstract

Some recent work on Ka Band Circular Linear-to-Polarizers carried out at the Microwave Group of University of Calabria (Italy) are presented. Four types of Linear Polarization (LP) to Circular Polarization (CP) converters, including three transmission type and one reflection type, are developed by using low cost standard Printed Circuit Board (PCB) technology. Experiments show that good performances are obtained for all proposed solutions.

1 Introduction

In Satellite Communication (SatCom) and Sensing systems, the advantages of Circular Polarization (CP) operation are well known. CP is commonly used to overcome the atmospheric absorptions, multipath unwanted reflections and Faraday rotation. Furthermore, in SatCom application CP simplifies receiver-transmitter alignment simplifying the ground segment operations in mobility and the installation process [1]. Over the years, many CP antenna examples have been reported in the literature. An alternative way to create circular polarization, is the use of linearly polarized antennas in combination with polarization converters. Various concepts for the implementation of polarizing surfaces in both reflect [2]–[4] and transmit mode [5]–[8] have been presented in the last years.

Transmission-type polarizers are anisotropic media, which convert linearly polarized signals to circular polarized signals when placed over a radiating aperture. One useful characteristic of this type of polarizer is the independence from antenna properties. Indeed, the converter may be thought as an add-on that affect the antenna performances in a limited way.

Planar polarization converters are implemented using periodic structures like frequency selective surfaces (FSS). These structures operate on the two orthogonal components of the incoming LP wave generating 90° phase shift between them.

In this paper, we report some recent progress on Ka Band [9]–[11] Circular Polarizers developed by the Microwave Group of the University of Calabria (Italy). In the following, four planar LP to CP polarizers, three in transmission and one in reflection are presented. Experiments show that good performances are obtained for all proposed solutions.

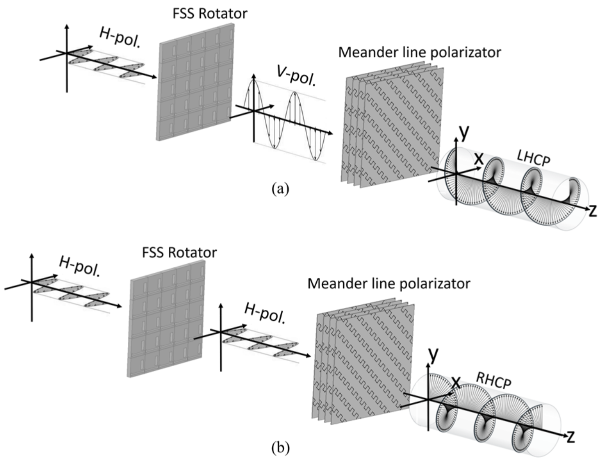

Figure 1. Operation principle of the linear to circular dual band polarizer at (a) RX frequency band (20 GHz) and (b) TX frequency band (30 GHz).

2 Dual-Band Converter based on a SIW Polarization Rotator

A Polarization Rotator based on Substrate Integrated Waveguide (SIW) has been proposed by the authors in [12], [13]. The rotator is designed as a dual band, single layer, FSS that transmits a wave rotated of 90-degree with respect to the incident field in one of the two bands, maintaining unchanged the polarization in the other one. Other than the design and characterization of the rotator, its application to a linear-to-circular dual band polarizer is also investigated as shown in Figure 1. To this purpose, the rotator is coupled to a conventional meander line polarizer generating orthogonal circular polarizations (CP) in the two bands.

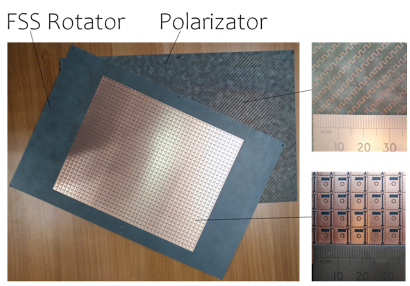

Figure 2. Fabricated planar FSS array using SIW and the meander line polarizer

This configuration is useful in SatCom applications where the required high isolation between TX and RX channels is obtained assigning orthogonal polarizations to the two bands. A prototype (Figure 2) is designed and experimentally validated in the SatCom K/Ka-bands. Measured performance shows an isolation between the TX and RX channels of more than 35 dB and insertion losses which do not exceed 1.5 dB in the two operating bands. Figure 3 shows the measured and simulated Axial Ratio (LHCP at RX band, RHCP at TX band) of the proposed configuration.

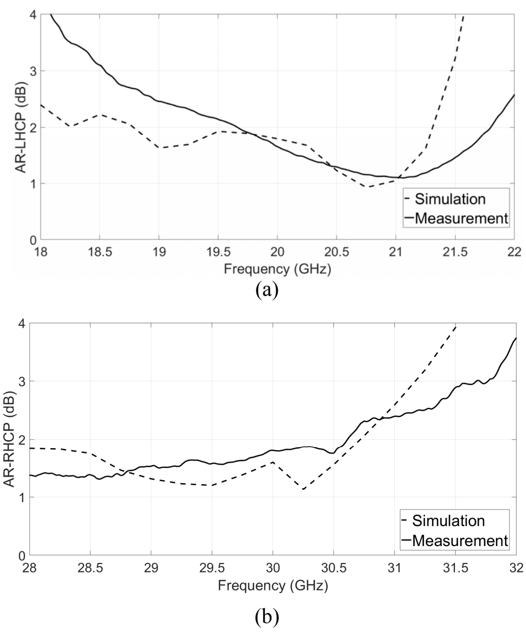

Figure 3. Measured (continuos line) and simulated (dashed line) Axial Ratio of the final configuration. (a) LHCP at RX band; (b) RHCP at TX band.

3 Wide-angle Scanning Converter Based on Jerusalem-Cross FSS

A broadband and wide-angle scanning linear-to-circular polarization converter based on a dual-layer structure has been designed using an elementary cell composed by conventional Jerusalem Crosses (JC) [14] as shown in Figure 4. The FSS is illuminated with an incident electric field tilted of 45° with respect to the *x* and *y* directions. The impinging E-field is seen as composed of its horizontal and vertical components. In the working bandwidth, both components are transmitted with no attenuation because the transmission coefficients are ideally equal to one. However, the x and y components experience different phase shifts accumulating a phase difference of 90° while propagating through the polarizer. Consequently, the polarization of the outgoing wave at the output of the polarizer will be circular. The design procedure is based on transmission line circuit model and on full-wave simulations. The proposed equivalent circuit has been generalized to include the oblique incidence in the model.

Simulated results demonstrate a 24% axial ratio bandwidth for an incidence angle =±50° in both *x-z* and *y-z* planes. Figure 5 shows simulated Axial Ratio for several angle of incidence.

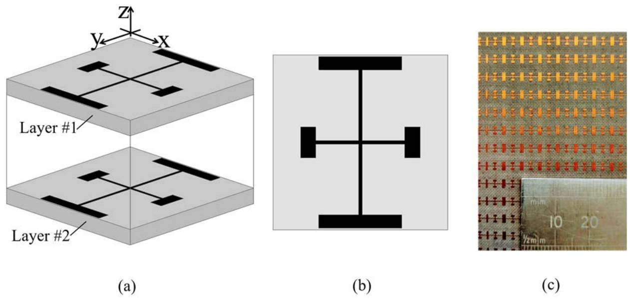

Figure 4. Configuration of the elementary cell: (a) 3D view; (b) top view. Layer #1 and layer # 2 have the same thickness. Crosses on two layers are identical. (c) Manufactured Prototype

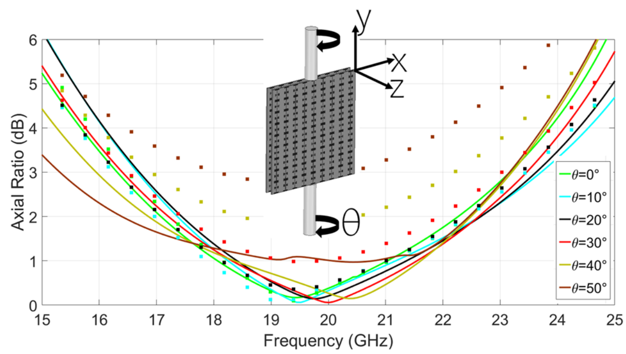

Figure 5. Simulated Axial Ratio for an incident wave propagating in x-z plane of incidence. Continuous lines: full-wave; points: equivalent circuit. The circuit model predicts the polarizer response acceptably only up to an angle of incidence of 30°.

A prototype has been realized (see Figure 4c) and measured to validate the proposed configuration. In comparison with other polarizers available in literature, the proposed converter offers a unique combination of wide bandwidth, thin profile, and stable response with respect to the angle of incidence.

4 Wide-Band Dual-Frequency Converter Based on Jerusalem-Cross FSS

Figure 6 shows a multilayer dual band linear to circular polarization converter operating at 18.5GHz-21.5GHz (Rx band) and 28.5GHz-31GHz (Tx band). The polarizer is composed by six metal layers printed on RO003 substrate. The upper three layers are realized with dog bone shaped strips optimized for the Rx band. The other layers are realized with Jerusalem Crosses, designed to convert the polarization in the Tx band. Foam spacers are used to separate the six layers. Similarly to the polarizer presented in the previous section the two orthogonal components of the impinging E-field is seen as composed of its horizontal and vertical components. The components experience different phase shifts accumulating a phase difference of +90° in the RX band and -90° in the TX band while propagating through the polarizer. Consequently, the polarization of the outgoing wave at the output of the polarizer will be RHCP and LHCP in the Rx and Tx band respectively.

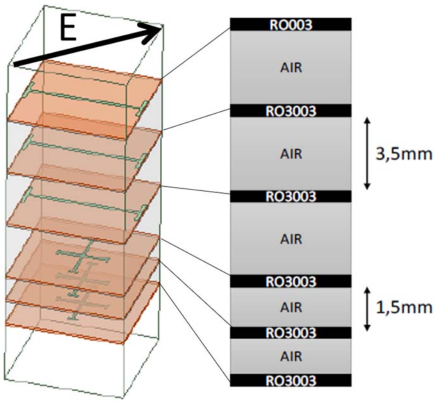

Figure 6. Configuration of the elementary cell. Orientation of the linearly polarized inpinging Electric field is also shown.

The simulated Axial Ratio of the dual band polarizer is shown in Figure 7. The 2dB axial ratio bandwidth is around 3.5GHz (from 18.3GHz to 21.8GHz) in RX band while around 3GHz (from 28.1GHz to 31.1GHz) in Tx band.

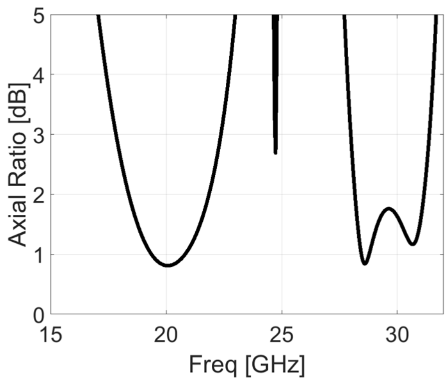

Figure 7. Simulated Axial Ratio. RHCP at Tx band, LHCP at RX band.

5 Dual-Band Converter in Reflection Mode

The elementary cell of a dual band LP to CP converter operating in reflection mode is shown in Figure 8. The proposed structure performs as a reflection polarizer within two Ka frequency bands, converting an incoming wave LP at slant 45◦ into an outgoing RHCP or LHCP wave in the Rx or Tx band respectively. The structure consists of two dipole-based FSSs separated by RT Duroid 5870 substrate. The upper dipole is designed to operate in the Tx frequency band, while the lower operates in the Rx band. The horizontal and vertical components of the 45° rotated impinging electric field (Figure 8b) experience different reflection phase. While the length of the dipole affects the resonating frequency, the width is used to control the reflection phase difference.

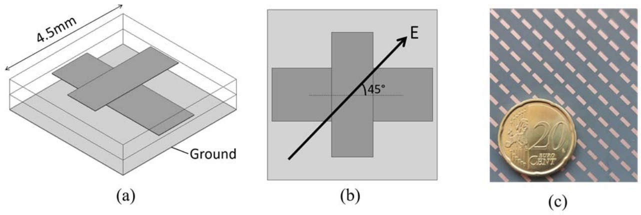

Figure 8. Configuration of the elementary cell: (a) 3D view (b) top view. (c) Manufactured Prototype.

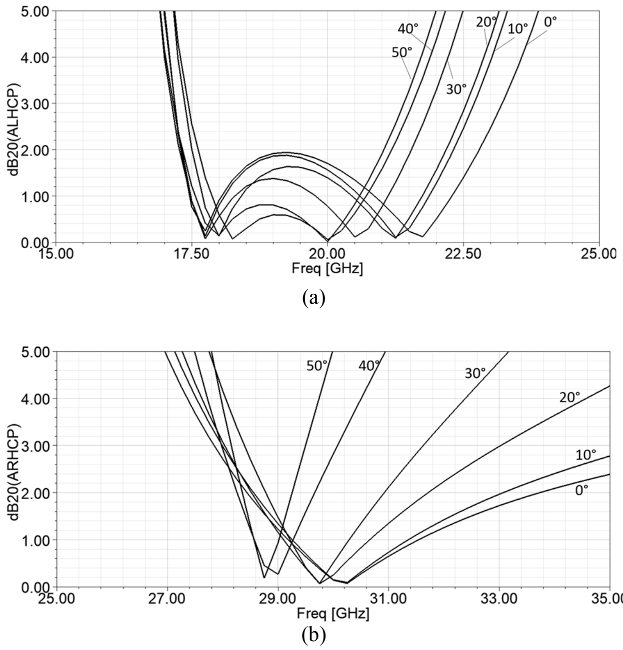

Figure 9. Simulated Axial Ratio for several angle of incidence (a) RHCP (b) LHCP

Figure 9 shows the simulated Axial Ratio for several angle of incidence. A prototype has been manufactured (Figure 8c) and measured. Experimental results are in good agreement with simulation.

6 Conclusions

Some recent design of Ka Band Circular Polarizers developed by the Microwave Group of University of Calabria (Italy) are presented. Four types of Linear Polarization to Circular Polarization converters including three transmission type and one reflection type were developed by using low cost standard Printed Circuit Board (PCB) technology.

The first converter is based on a polarization rotator in SIW technology used in combination with a meander line polarizer to ensure dual band operation. The second converter uses a conventional JC elementary cell to provide broadband and wide-angle scanning performances. In the third polarizer, dog bone strips in combination with JCs are used in a multilayer configuration to ensure wide-band dual-frequency behavior. Finally, a dual band converter in reflection mode has been developed to operate in two Ka frequency bands converting an incoming wave LP at slant 45◦ into an outgoing RHCP or LHCP wave in the Rx or Tx band respectively. The structure consists of two dipoles based FSSs separated by a dielectric substrate.

Simulations and experiments show that good performances are obtained for all proposed solutions.

7 References

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