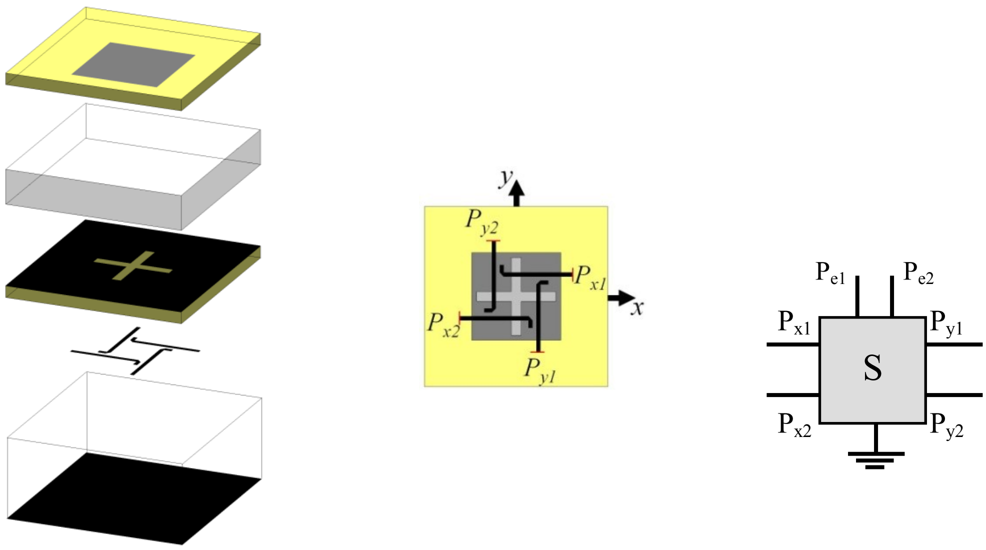
POS1-16

Reflectarray Element for Beam Scanning with Polarization Flexibility

Eduardo Carrasco[1], Mariano Barba[2], Jose A. Encinar[2], Julien Perruisseau-Carrier[1]
[1] Adaptive MicroNano Wave Systems, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland,
e.carrasco@ieee.org
[2] Electromagnetism and Circuit Theory Dep., Universidad Politécnica de Madrid (UPM), Madrid, Spain,

1. Introduction

Reflectarray antennas are very attractive notably because of their low loss, planar profile, easy deployment and low cross-polarization, thereby combining the best features of both conventional arrays and parabolic reflectors [1]. The recent improvements in technology platforms for RF dynamic control, notably Micro-ElectroMechanical Systems (MEMS) [2]-[4], allows to implement beam-scanning reflectarrays to be used in different applications, as satellite communication, synthetic aperture radars (SAR), satellite reception from moving vehicles, emergency communications, etc. The main drawback of reflectarrays is their moderated bandwidth, but in recent years much progress has been made in this regard [5]-[6], increasing their potential. Particularly, aperture-coupled elements can compensate the effects of the differential spatial phase delay by the introduction of true-time delay (TTD) lines. On the other hand, depending on the application dual linear polarization (LP) or circular polarization (CP) must be chosen. This contribution proposes a reflectarray element which can allow to electronically control the phase of the reflected field controlling at the same time its polarization if control devices are implemented. This means that the element can be feed by an LP field (V, H or both) or one CP (RHCP or LHCP), while reflecting the field with any polarization, depending on the specific time-dependent requirements [7].



(a) (b) (c)

Figure 1: Flexible-polarization reflectarray element. (a) Expanded view. (b) Upper view. (c) Scattering matrix representation for the proposed reflectarray element.

2. Reflectarray element with phase control and independent polarization

The proposed element is shown in Fig. 1 and has been designed to operate at the central frequency of 9.65 GHz, with a period of 18.5 mm (0.59 λ). It consists of a square patch which is coupled through a cross slot to four microstrip lines. The cross slot allows to keep the symmetries and therefore to obtain exactly the same behaviour in both linear polarizations, a very linear phase response and low cross-polarization. The scattering matrix of the element has been obtained by a full-wave simulation using CST Microwave Studio®[8] modelling the variable length lines with guided ports P_{x1}, P_{x2}, P_{y1} and P_{y2}. The impinging plane wave with the corresponding polarization is modelled with the ports P_{e1} and P_{e2}. The reflection coefficient in free space for each desired polarization can be obtained by adequately loading the ports with the corresponding delay line segments which can be connected by switches (implemented in a real element with diodes or MEMS) and the corresponding excitation using a circuit approach, as will be explained in the following sections.

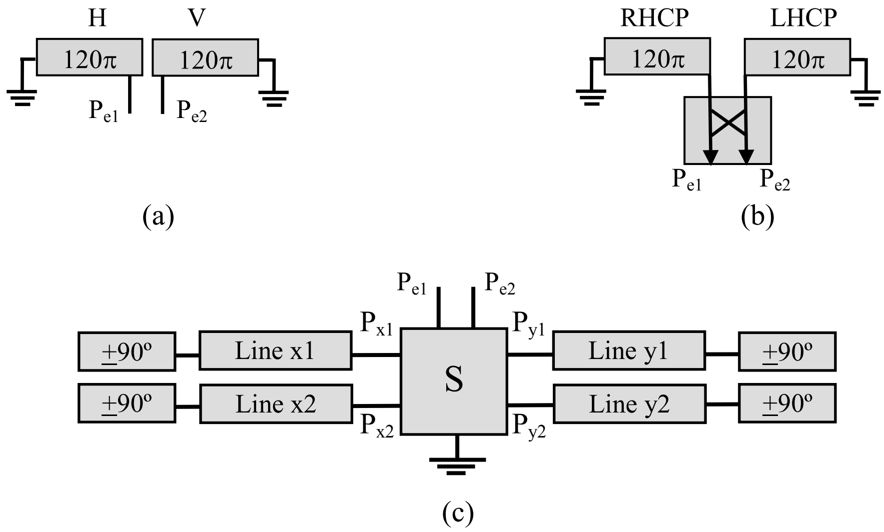
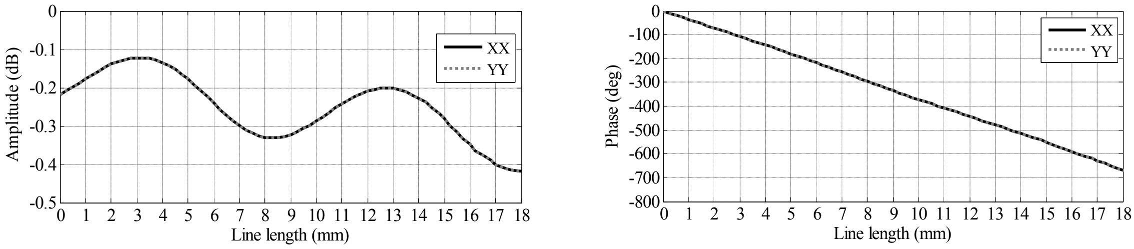


Figure 2: Circuit approach for the flexible-polarization reflectarray element loaded with microstrip delay lines with variable length. (a) Excitation loading using two linear polarizations. (b) Excitation loading using two circular polarizations.

2.1 Dual linear polarization

According to Fig. 2, the element can be fed by two linear polarized waves and thus the intrinsic impedance of air, $Z_o=120\pi$, loads P_{e1} and P_{e2}. Under this condition, if the four line ports are loaded with delay lines of the same length, the reflected field will remain LP. On the other hand, if P_{e1} and P_{e2} are loaded with CP waves, represented in the Fig. 2(b) by the hybrid network, the reflected wave can be changed to LP by compensating the corresponding 90º in the *x* (H polarization) or *y* (V polarization) pair of lines. Fig. 3 shows the amplitude and phase of the reflection coefficient in free space for both H and V polarizations when impinges a dual-linear polarized wave. The average losses are 0.25 dB, while the phase response is very linear, proportional to twice the length of the delay line. It is well known that the cross polarization levels for these kind of elements are negligible for normal incidence, therefore the cross polarization must be evaluated for oblique incidence. Fig. 4 shows the computed cross polar component for different incidence angles of the locally plane wave. XY means the field reflected along x-axis when a y-oriented field impinges with the corresponding angle of incidence, while YX means the field reflected along y-axis when an x-oriented field is impinging. As can be seen, the cross polar components are below –20 dB for practically all the lengths of the delay line, even for very oblique incidence angles, demonstrating a good isolation between both linear polarizations. Additionally, for beam-scanning applications, different delay lines can be in series connected with switches with the aim of change the length of the delay lines and therefore the phase of the reflected field. Fig. 5

shows the response of the proposed element when three ideal switches (represented in the simulations by short and open circuits) are used. It can be seen that the four states has a lineal phase variation with the frequency in the band from 8.65 GHz to 10.65 GHz, demonstrating the feasibility of using the proposed element in reconfigurable-beam applications.



(a) (b)

Figure 3: LP reflection coefficient for the proposed element at 9.65 GHz. (a) Amplitude. (b) Phase.

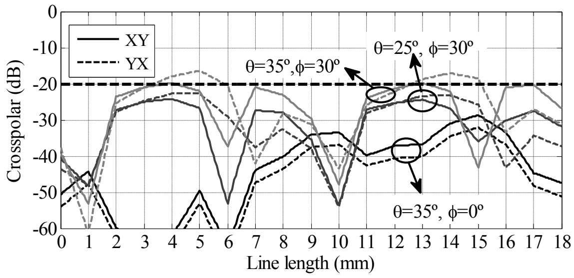
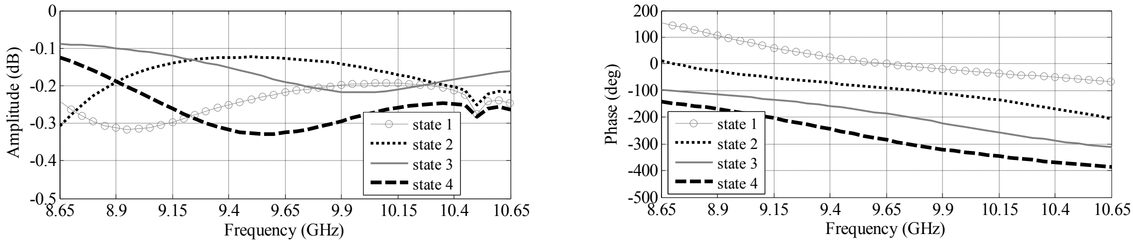


Figure 4: Cross-polar component for the proposed element for oblique angles of incidence.



(a) (b)

Figure 5: Two-bit element in the 8.65 GHz to 10.65 GHz bandwidth. (a) Amplitude. (b) Phase.

2.1 Circular polarization

CP results very attractive in radar and mobile satellite communications. When the phase difference between the two orthogonal components of the electric field is 90º and the amplitude remains equal, the electric field vector as a function of time will describe a circle. According to Fig. 2, if the reflectarray is illuminated with a dual LP field, the corresponding RHCP or LHCP can be produced by introducing a 90º phase delay difference ($\lambda/8$ segment because of the reflection performance of the line) in one pair of the *x* or *y* oriented delay lines. If the reflectarray is directly illuminated with CP, only the phase variation must be equally produced in the four delay lines. Fig. 6 shows the amplitude and phase of the reflection coefficient in free space for the element when an impinging CP field is reflected. Here is important to note that, the reflected copolar component corresponding to a RHCP field will be LHCP, in concordance with the hybrid representation of the CP excitation. The Fig. 6(b) shows that the reflection is zero at each entrance of the hybrid network as a result of the polarization shift. Once again a very linear phase response is obtained.

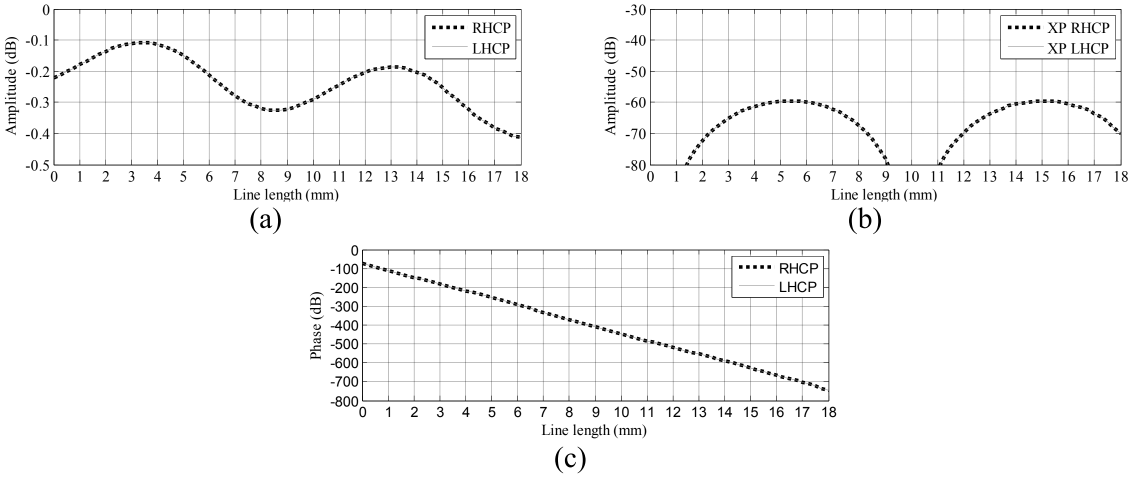


Figure 6: CP reflection coefficient for the proposed element at 9.65 GHz. (a) Amplitude. (b) Crosspolarization (c) Phase.

4. Conclusions

A reflectarray element with flexible polarization which can be used in scanning antennas has been preliminary analysed with very promising results for a future implementation. The proposed element allows radiating a beam with dual-linear polarization or a single circular polarization independently of the polarization used to feed the antenna. If some switches are introduced in the delay lines, both the phase of the reflected field and the polarization of the element could be controlled.

Acknowledgments

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