Multi-Frequency Polarizarition Converter With Enhanced Angular Robustness

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***Abstract*—This paper presents a multi-frequency polarization converter for linear polarized waves. The reflection-based polarization converter is realized with a periodic surface. The unit cell comprises loaded dipoles printed on a metallic backed Teflon substrate 1.52mm thick. The unit cell topology results to be robust to the variation of the azimuthal incident angle. For this reason, the proposed device is particularly suitable for applications in which the direction of arrival of electromagnetic wave is unknown.**

Keywords—polarization converter; linear polarization; periodic surfaces.

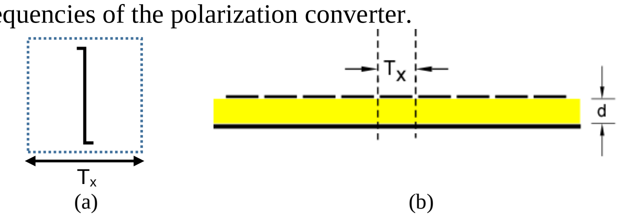
I. Introduction

The possibility of controlling the polarization of an electromagnetic wave is a particularly desirable characteristic in several electromagnetic applications. For this reason, polarization converters have been object of numerous studies, particularly in recent years. Common applications are related to microwave communications and antennas [1]. They are also used to perform millimeter-wave and sub-millimeter wave imaging and remote environmental monitoring, or to realize microwave devices such as circulators and isolators [2]. Polarization converters are widely applied in optical instrumentation. Typically, they are realized with optical gratings and dichroic crystals [3]. In recent years, the use of metamaterials for the realization of polarization converters has been proposed. These metamaterials can be employed for designing birefringent materials, anisotropic material and chiral material. By using a suitable design approach, a great number of interesting metamaterial-based devices can be developed by means of metal-dielectric structures, such as high-impedance surfaces [4]. When these particular surfaces are supported by a ground plane, they are able to manipulate the polarization state of reflected electromagnetic field impinging on the surface. In fact, they are able to directly reflect the impinging wave with a particular phase shift and a particular amplitude tapering depending on the local impedance of the surface. In some applications, such as chipless RFID [6], [7], it is necessary to design the polarization converters with a shallow profile and able to work on multiple frequencies. An effective way to achieve reflection polarization converters is to utilize periodic surfaces which employ dipole structures obliquely oriented with respect to the incident electric field. The main limitation of this structure lies in the variation of the performance of the dipole in respect to the azimuthal angle of the incoming electric field. In fact, when the angle of incidence is 45°, the dipole is able to successfully convert the polarization but when the angle of incidence deviates from the value of 45°, the performance of the dipole degrades significantly.

The purpose of this work is to design a multi-frequency linear polarization converter, which is robust to the variation of the azimuthal angle of the incoming field. To this aim, a metamaterial is designed by means of a periodic surface formed by meandered dipoles. Resonant frequencies are chosen by suitably tailoring the length of the loaded dipole and the periodicity of the surface. In addition, it is possible to choose the number of working frequencies that are related to the number of resonant elements of the unit cell. The azimuthal robustness of this device is particularly desirable in applications such as chipless RFID in which the direction of arrival of the incoming wave is unknown.

II. Multi-Frequency Polarization Converter

The multi-frequency polarization converter is characterized by multiple resonant elements, one for each working frequency. The resonators are printed on a single dielectric layer backed by metallic ground. The aim of the present work is to improve the polarization conversion capabilities of the dipole which is able to convert the polarization only when the angle of incidence approaches 45°. Preliminary studies were carried out in order to identify the unit cell that permits the improvement of the polarization conversion capabilities of the dipole with respect to the azimuthal angle of the incident electric field [8]. The unit cell that has been selected for the design of the multi-frequency polarization converter, is reported in Fig. 1 (a). The radiating element consists of a dipole of length equal to 2.35 cm printed on a Teflon (ε_r=2.33-j 0.002796) layer of thickness d=1.52mm. The dipole is loaded with a stub with a length of 1.6mm. The unit cells are arranged in a square lattice with periodicity Tx = 2.5cm. The polarization converter stack-up is reported in Fig. 1 (b). By modifying the length of the loaded dipole and the periodicity of the lattice, it is possible to select the working frequencies of the polarization converter.



(a) (b)

Fig. 1 - Unit cell (a) and stack-up (b).

The loaded dipole improves the cross-polar conversion capabilities of the dipole with respect to the azimuthal angle.

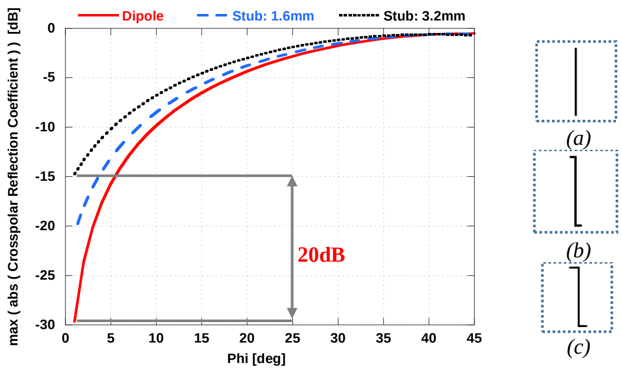


Fig. 2 – Maximum of the cross-polar reflection coefficient in function of the azimuthal angle for the case of the dipole (a) and loaded dipole with stub of 1.6mm (a) and 3.2mm (b).

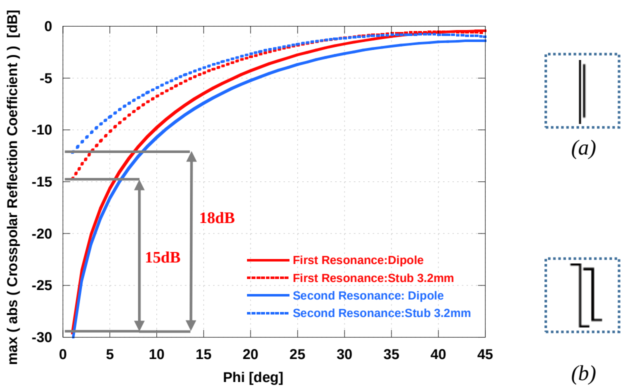


Fig. 3 - Maximum of the cross-polar reflection coefficient in function of the azimuthal angle for the case of two dipole (a) and two loaded dipole with stub of 3.2mm (b).

This is due to the anisotropy introduced by the horizontal stub with a consequent increase of the cross polar component of the scattered field. The amplitude of the cross-polar reflection coefficient as a function of the frequency has been calculated for different values of the azimuthal angle ϕ ranging from 0° to 45°. In order to assess the behaviour of the unit cell with respect to the ϕ angle, the maximum values of these curves, which are present at the resonance frequency of the loaded dipole, have been collected and plotted as a function of the ϕ angle. In this way, the curves of Fig. 2 have been obtained. The curves have been calculated for the lengths of 1.6mm (Fig. 1 (a)) and 3.2mm (Fig. 1 (b)) of the horizontal stub. The figure shows that the loaded dipole (*b*,*c*) can considerably enhance the performance of the dipole (*a*) when the angle approaches 0°. As it is evident from the graph, the improvement of the polarization conversion performance obtained by employing the loaded stub is remarkable. In particular, for an azimuthal incidence angle approaching to 0°, the loaded dipole gains about 15dB compared to the dipole. By increasing the length of the stub, the cross-polar response of the loaded stub can be further improved.

In order to design a dual-frequency polarization converter robust to the variation of the azimuthal angle, two loaded dipoles with different lengths can be employed. The performances of two different unit cells based on two dipole loaded with stubs of length 1.6mm (a) and 3.2mm (b) have been analysed.

The amplitude of the cross-polar reflection coefficient as a function of the frequency, for the case of three (a), four (*b*) and five (*c*) loaded dipoles is shown in Fig. 4. Thanks to the particular topology of the unit cell presented in this paper, it is possible to remove or to add working frequencies without affecting the other resonant elements.

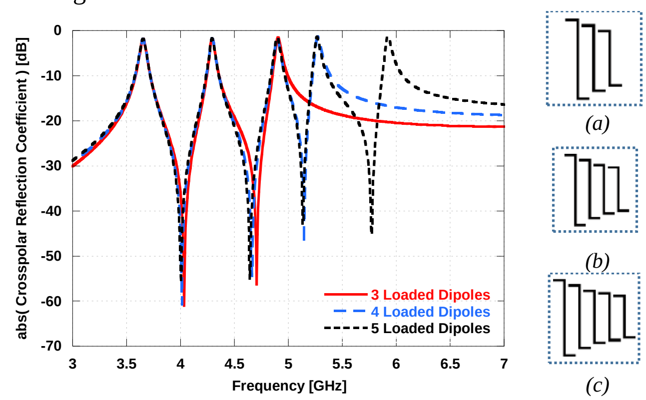


Fig. 4 - Amplitude of the cross-polar reflection coefficient as a function of the frequency for the case of three (a), four (b) and five (c) loaded dipoles.

As shown in Fig. 4, the introduction of a further loaded dipole does not modify the position of the other working frequencies. The maximum number of working frequencies of the polarization converter, is limited by the maximum number of dipoles that can fit in a single unit cell.

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