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Circular Polarization Advantages for Chipless RFID and Sensor Design

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Abstract

The transmission of the interrogating signal and the collection of the backscattered field are the two key operations of a radiofrequency identification process. These two phases are linked together by the presence of the channel, which unavoidably alters the transmitted signal, as well as by an intentional transformation of the signal operated by a device exploiting a certain mechanism to encode information. From the collected signal it is possible to decode an identification number but also some data related to a sensing function implemented in the device. This work illustrates the benefits of using circularly polarized interrogating waves, with respect to linear one, in the case of a chipless RFID system operating in a real environment.

1 Introduction

In a chipless Radio Frequency Identification system (RFID) the reader interrogates with an electromagnetic wave the passive tag which, in turns, reflects back the impinging power toward the reader. The amount of the scattered power obviously depends on the geometric area of the tag that contributes to the Radar Cross Section (RCS) of the chipless tag. However, the transmitted signal interacts with all the object surroundings the chipless RFID tag that determine an additional scattered field reaching the reader. In order to have an intelligible signal coming from the chipless RFID it is necessary to provide a design solution that allows to discriminate between the electromagnetic echo coming from the tag and that one of the environment. This task can be straightforwardly accomplished employing a large area chipless tag with a RCS significantly high. In this way, the power backscattered by the tag is larger than the overall one determined by the objects in the operative scenario (Fig.1).

However, a large chipless RFID tag can be cumbersome and impractical. Additionally, copolar interrogation schemes usually suffer from unacceptable decoding performance when the chipless RFID tag is placed on a metallic object. In this case, the scattering of the tag can be overwhelmed by the strong electromagnetic echo of the hosting platform. One interesting workaround consists in having a backscattered signal with a polarization different from the one of the interrogating one. For instance, the field reflected by a suitably designed chipless RFID tag might be orthogonal to the one produced by the interaction with the environment. Consequently, it is possible to correctly detect the tag response even if its power is comparable or even lower then undesired signal backscattered by the surrounding environment. This solution has been pursued in studies employing dual polarization interrogation [1] or cross-polarization [2], [3], which rely on techniques based on depolarizing tags that are more efficient in isolating the tag contribution from the environment one [4]. Unfortunately, these approaches are prone to a system overall degradation when the relative orientation between the tag and the transmitter/reader antennas is not the one that maximizes the crosspolar scattered field.

The adoption of a circularly polarized waves has proven to be beneficial for the overall system performance when a communication takes place in a complex propagating scenario [5]. Similarly, a circularly polarized interrogating signal could solve both the undesired effect of the field scattered by the surrounding objects as well as providing the maximum chipless RFID backscattered field independently from the relative orientation of the tag with respect to the impinging signal [6].

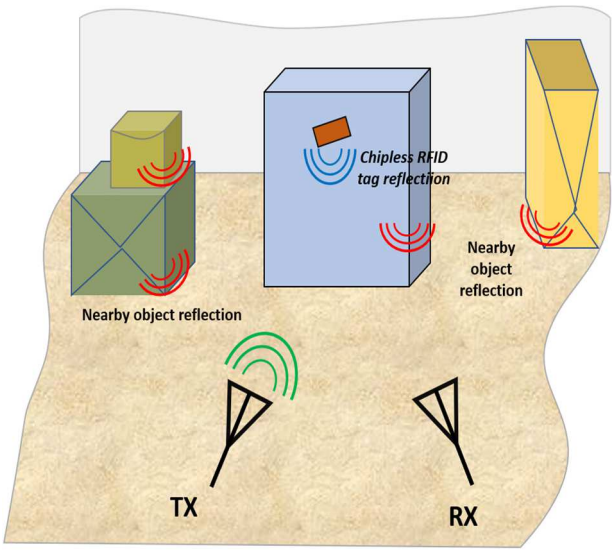


Figure 1. Example of operative scenario: the transmitter (TX) interrogates the chipless RFID tag and the receiver (RX) collects the field backscattered from the surrounding objects.

2 Reflection of Circular Polarization and Linear Polarization

Let us consider a right-handed circularly polarized (RHCP) plane wave propagating along $+z$ direction that impinges on a planar interface. The incident field $\underline{E}^{inc}$ can be written as [7]:

$$\underline{E}^{inc} = E_0\, \underline{i}_x + jE_0\, \underline{i}_y \tag{1}$$

where $\underline{i}_x$ and $\underline{i}_y$ are the unit vectors along x-axis and y-axis, respectively, and E_0 represents the magnitude of each component. The reflected electric field $\underline{E}^{ref}$ is equal to:

$$\underline{E}^{ref} = \Gamma_x E_0\, \underline{i}_x + j\Gamma_y E_0 \underline{i}_y = \underline{E}_x^{ref}\, \underline{i}_x + \underline{E}_y^{ref}\, \underline{i}_y \tag{2}$$

where Γ_x and Γ_y are the copolar reflection coefficients. In case the interface is between air and a perfect electric conducting (PEC) surface, (*i.e.* $\Gamma_x = \Gamma_y = -1$) the reflected wave is still CP but its handedness is opposite. The receiving antenna will see the backscattered wave as:

$$\underline{E}^{ref} = -E_0\, \underline{i}_x - jE_0\, \underline{i}_y \tag{3}$$

which can be fully collected with a left-handed (LH) CP antenna. On the contrary, the received power at the receiver will be zero. Let us consider a case in which the two components of the CP plane wave undergo a reflection with $\Gamma_{xx} = 1$, $\Gamma_{yy} = -1$. In this case it can be easily proven that only a right-handed (RH) CP antenna is able to maximize the received power. The interesting implication of such kind of reflection is that it is naturally uncoupled with the one coming from a PEC structure. Moreover, it is plausible to assume that the latter considered reflection case does not happen by random interactions with the environment, but it has to be carefully designed on purpose. Therefore, this feature seems appealing for a chipless RFID tag since the backscattered field containing the information could benefit from this intrinsic mismatch with the reflection coming from surrounding object, even metallic ones. It is also important to underline that this property is retained regardless of the chipless RFID tag orientation since CP guarantees the insensitivity to this parameter.

In order to highlight this additional benefit provided by the CP illumination, it is interesting to analyze the difference with respect to strategies based on cross-polarization exploitation. The conversion of an arbitrarily oriented linearly polarized incident field (Fig. 2a):

$$\underline{E}^{inc} = E_0 \cos(\phi)\, \underline{i}_x + E_0 \sin(\phi)\, \underline{i}_y \tag{4}$$

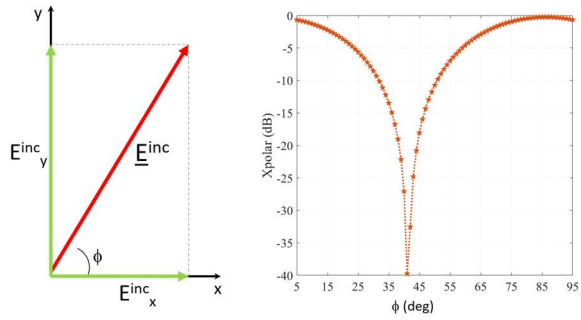
into a cross-polar reflected one can be described by using a notation consistent with the previous one as:

$$\begin{aligned} E_x^{ref}(\phi) &= E_x^{inc}(\phi)\,\Gamma_{xx} + E_y^{inc}(\phi)\,\Gamma_{xy} \\ E_y^{ref}(\phi) &= E_y^{inc}(\phi)\,\Gamma_{yy} + E_x^{inc}(\phi)\,\Gamma_{yx} \end{aligned} \tag{5}$$

Finally determines

$$E_{Xpolar}^{ref}(\phi) = \hat{z} \cdot \left(\underline{E}^{inc}(\phi) \times \underline{E}^{ref}(\phi) \right). \tag{6}$$

A representative behavior of the cross polar response of a depolarizing surface is shown in Fig.2b. It is apparent that the magnitude of the scattered field greatly varies as a function of the linear field orientation, regardless of the particular reflecting surface considered. This is obviously undesired since an inefficient conversion to crosspolar backscattering can seriously undermine the intelligibility of the decoded information with respect to the environment clutter and thus the overall system performance.



(a) *(b)*

Figure 2. Arbitrarily oriented linear polarized incident field impinging at the interface *(a)* and typical cross polar response of a depolarizing surface *(b)*.

3 Conclusions

The benefits obtained by the adoption of chipless RFID tags sensitive to circularly polarized interrogating field will be theoretically analyzed and demonstrated by measurements shown at the conference.

4 Acknowledgements

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5 References

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