A Novel Phase Encoding Technique Exploting Linear or Circular Polarization

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***Abstract*— The phase response of an High-Impedance Surface (HIS) to an incident plane wave linearly polarized is employed in order to realize a chipless RFID with phase-only encoding. The encoding is obtained by using stubs of different length applied to each single loop included in the unit cell. The information is encoded in the difference between the TE and TM phase response of the tag. Possible improvements of the proposed structure in terms of increased bit capacitance and robustness are also investigated.**

Index Terms— Chipless RFID, phase encoding, linear polarization, circular polarization, High-Impedance Surfaces (HISs).

I. Introduction

Radio Frequency Identification (RFID) is nowadays employed in a vast field of applications spanning from identification to toll collection, from goods tracking to localization [1]-[3]. The most part of RFID tags present today in the market is passive (*i.e.* without an internal power source) and generally it consist of an antenna connected to a chip. The probing wave induces in the antenna tag an electrical current able to power the integrated circuit which in turns modulates the backscattered signal toward the reader. In this way the information is transferred by using the modulation and without any battery since the tag is a completely passive transponder.

Although the cost of the RFID tags is low, they cannot compete with barcode in terms of cost especially for low-price items. However, a new class of RFID tags, commonly referred as "chipless", has recently gained attention since they represent a good trade-off in terms of low cost and operational potential with respect to the barcode and to the tag equipped with a chip [4]-[8]. Without resorting to a modulating chip to process the information, the data is encoded in the electromagnetic response of the tag. In this framework the unique electromagnetic footprint of each tag has been implemented by using different techniques. The first one relies on encoding data in the frequency spectrum of the chipless RIFD response by using resonators [5], [9] to turn on/off resonances at some predefined frequencies. These tags allow achieving quite good bit-capacity for a chipless RFID, but they often require a large footprint. Another technique is based on the phase response [10], [11] although tag dimension can be an issue also for this solution. A different solution take advantage of time-domain techniques in order to extract the useful information from the chipless RFID tag response [8], [12].Another possible encoding mechanism can take advantage of the cross-polarization effect of the chipless tag [13],[14].

An important feature of RFID chipless tags is that they do not need to be interrogated with an amount of power sufficient to turn on the chip but they simply scatter the impinging wave on the basis of their radar cross section. This property determines a longer read range with respect to the chip-equipped RFID for an equal transmitted power [15]. Their simplicity and intrinsic robustness due to the absence of damageable IC make them ideal for applications in hostile environments or extreme conditions. The price of this benefit at tag side is paid in term of the increased reader complexity and difficulties in recovering the encoded data in real scenarios.

A study on the exploitation of the polarization of the probing wave in order to improve the recovering of information stored in a chipless RFID tag is presented in this work. In particular, the theory of periodic surfaces such as Frequency Selective Surfaces (FSSs) [16] and High-Impedance Surfaces (HISs) [17], [18] will provide the basis of the analysis of the frequency response of the proposed RFID chipless tags.

II. Incident Plane Wave with Linear Polarization

As previously said, in the case of an RFID chipless system the reader has an even more important role that the case of an RFID equipped with IC. This means that we can explore configurations that exploit more than a simple state of polarization of the interrogating wave for achieving the desired performance, for example in terms of reading range. information density or robustness.

One of the candidate solution is represented by the codification of the information in the difference between the phase response of a chipless tag when illuminated by two plane waves, one with TE linear polarization and the other with TM linear polarization. Let us consider the properties of the periodic surface whose unit cell is illustrated in Fig. 1. The structure consists of a grounded dielectric substrate with a series of metallic N nested rectangular loops printed on the top face. A stub of generic length S_i ($i = 1,2,3,4$) is attached in correspondence of the four corners of each one of the loop. The periodicity of the unit cell is equal to T_x and T_y along x and y axis, respectively (Fig. 2). The dimension of each one of the N loops is equal to D_{ax} in x-direction and D_{ay} in y-direction (in this case $a = 1,2,3,4$). If we look at the phase response of the periodic infinite screen for a set of values of S_i (*Set#1*) at a frequency f_1 (for example $f_1 = 5$GHz in Fig. 3) , we can see how the TE and TM response changes if the set is modified

(*Set#2*). This can be exploited to encode the information under the form of the phase difference at frequency f_1.

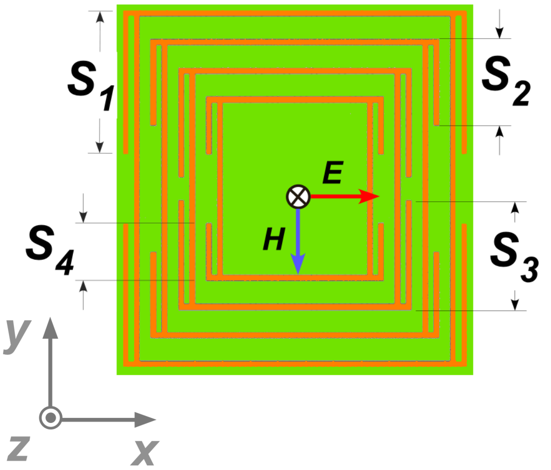

Fig. 1. Top view of the unit cell of the periodic surface investigated. Normal incidence of a TE plane wave.

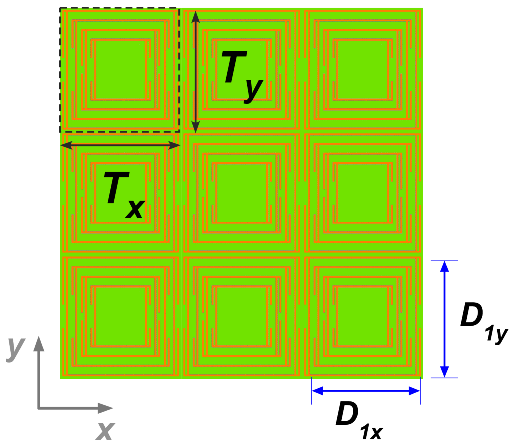

Fig. 2. Example of a stubbed multi-ring chipless RFID tag comprising 3x3 unit cells.

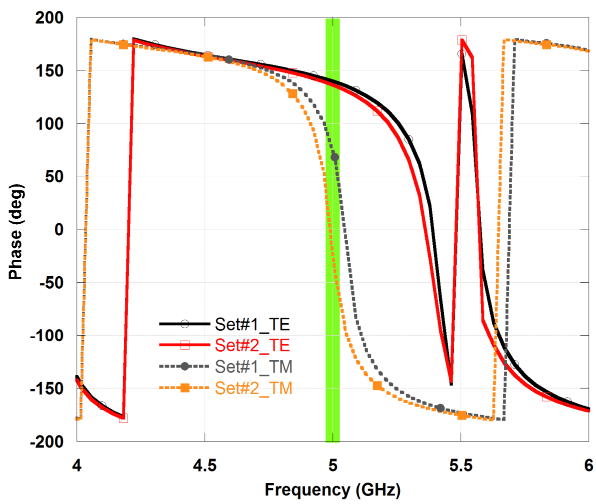

Fig. 3. Different phase response for a TE and TM incident plane wave for different set of stubs (*Set#1* and *Set#2*).

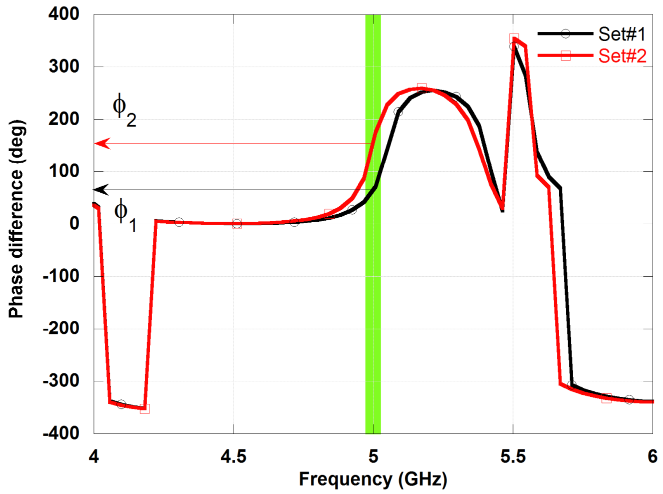

Fig. 4. Phase difference for a TE and TM incident plane wave for different set of stubs (*Set#1* and *Set#2*).

In fact, in Fig. 4 the *Set#1* determines a phase difference equal to ϕ_1 whereas, at the same frequency f1, the *Set#2* produces a phase difference of ϕ_2.

Clearly, the number of independent frequencies that can be used depends on the number of rectangular loop nested in the unit cell since each loop determines a resonance. More details on the underlying physics can be found in [5]. On the other hand, the number of different sets that can be allocated in one frequency mainly depends on the resolution of the circuit printing technology adopted and the losses in the substrate [18].

Obviously, we need to truncate the surface and an example of a finite RFID chipless comprising 3x3 unit cells is reported in Fig. 2. For a chipless RFID tag working within the frequency bandwidth between 2.5 GHz-8.0 GHz, the dimension of the tag is in the order of few tens of square centimeter, thus offering a tag footprint which can be considered small if compared to the most part of existing chipless tags.

The probing configuration can be realized with a dual-polarized horn but also two linearly polarized multi-resonant antenna may be sufficient. In this second case the probing system can be realized with standard printed circuit technology thus reducing the cost of the overall system.

The ongoing research is focused on extending this encoding system by using a circular polarized plane wave in order to increase the robustness of the system and the number of encoded bits.

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