Potentialities of Dual-Polarized Interrogation for Spectral Domain Chipless Tags

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***Abstract* — The paper proposes an encoding mechanism for chipless RFID relying on two orthogonally polarized measurements. The paper shows that a dual polarized acquisition, which can be made simultaneously, can be a promising and viable solution for solving the typical calibration-dependent reading which limits the practical applicability of chipless RFID technology.**

***Index Terms*—antenna, propagation, measurement.**

I. INTRODUCTION

Radio Frequency Identification is today a rapidly growing technology which allows the tagging of items by using microwaves 0. The use of the RFID could replace Barcode in order to overcome typical limitations of item tagging such as short-range readability, non-automated tracking, operation in harsh environments, etc.. However, the degree of penetration in the market is strongly correlated to the unit price of a tag. Industries will accept to change the item tagging technology only when their investment will be profitable. The application of RFID to low value objects is feasible only if tag prices drop under one cent including the cost of fitting them in place. The presence of the integrated circuit poses a lower bound to the cost of conventional chip-equipped tags [2]. For this reason chipless RFID technology [2], [3] has gained a renewed interest in the last few years. In terms of performance chipless tags have some limitations with respect to the conventional ones (more limited number of bits, wideband occupation for spectral based chipless tags) but also some advantages (operation in harsh environment, low cost). The main attractive characteristic of chipless tags is the cost: such tags could be printed directly on products as the barcode for less than 0.1 cents. For the aforementioned reasons, chipless technology could represent a good tradeoff between optical barcode and RFID tags.

Two general categories of RFID tags operating in the time domain (TD) or in the frequency domain (FD) have been investigated until now. Two promising types of TD tag are the surface acoustic wave (SAW) tag [4] and the Thin Film Transistor Circuits (TFTCs) [3]. However, these types of tag are not low-cost at the present time. Since the extremely low bit capacity achieved with low-cost TD chipless tags [5], the spectral-based tags have been more frequently investigated [6]-[10]. The advantages of FD tags are that they are fully printable and extremely low cost. Several configurations have been proposed until now but none of the proposed designs is enough mature for a practical implementation in a real scenario. The problems to be solved typically regard the number of encoded bits and the reliability of the reading procedure in a real environment where multipath phenomena and the presence of other objects render it extremely problematic. Another big issue to be solved is the normalization procedure which is commonly needed to recover a bit sequence in laboratory experiments: the normalization procedure typically needs of two or even three measurements (scenario with tag, scenario without the tag and the scenario with a PEC of the same dimension of the tag). The normalization is necessary since chipless tags are static devices and only one backscattered signal is available. Conversely, in conventional chip-equipped ones the encoded bit sequence can be estimated by a comparative measurement between two states of the chip (e.g. open and the chip impedance load). Unfortunately, in a real scenario, the additional acquisitions of the environment without the tag are not feasible and thus the estimation of the information encoded by the tag is possible only in a few situations where a kind of normalization is still possible (for example the case of a conveyor belt or those cases where the tag is in movement with respect to the interrogating antenna). In other cases the absence of a reference makes the reading of the tag nearly unfeasible.

This paper investigates the potentialities of a dual polarized interrogation of chipless tags which could efficiently exploited to avoid any normalization procedure. The tag configuration here adopted is formed by an artificial impedance surface comprising a periodic surface that includes several resonators. The frequency selective surface (FSS) is printed on the top of a thin grounded dielectric slab. The configuration is preferred to other layouts for the following reasons: the tag is dual polarized, the RCS can be modulated by only increasing or decreasing the number of unit cells, the analysis can be efficiently carried out through a quick IE-MoM (Integral Equation – Method of Moments) simulation of a single unit cell. Two possible unit cells configurations able to provide a platform for the proposed encoding schemes will be presented in the next section.

II. ENCODING SCHEMES BY USING DUAL POLARIZED TAGS

Through the simultaneous acquisition of two orthogonal reflection measurements, a number of possibilities are opened depending on the combination of the received signals. For instance, if two slightly shifted frequency responses are reflected by the tag, the signals can be profitably combined (summed or subtracted) to retrieve the resonant peaks of the spectral response. The aforementioned response can be obtained for example by employing a rectangular loop resonator or a square loop resonator loaded with slightly different stubs along two planar orthogonal planar directions. The two reflection measurements can be collected by using a dual polarized antenna. The layout of two possible passive devices providing two slightly shifted stop-band frequency responses are shown in Fig. 1. The configuration comprises a single or multi-loop rectangular loop resonator printed on top of a grounded lossy dielectric. The device can comprise one or more unit cells. The number of unit cells employed will determine the average value of Radar Cross Section (RCS) and therefore the read range. Generally a size of 2x2 unit cells, that is 30 x 30 mm^2, leads to a sufficient level of scattered power to detect the tag a distance of 1 meter [9], [10].The proposed resonator is characterized by well visible absorption peaks. The peaks obtained with vertical or horizontal polarizations are slightly shifted in the spectrum depending of the degree of stretching of the loop. By subtracting the reflected signals obtained with two interrogations of the tag, it is possible to obtain well visible spikes in correspondence of every resonance frequency. The smaller is the frequency shift the higher is the Q-factor of the subtracted responses.

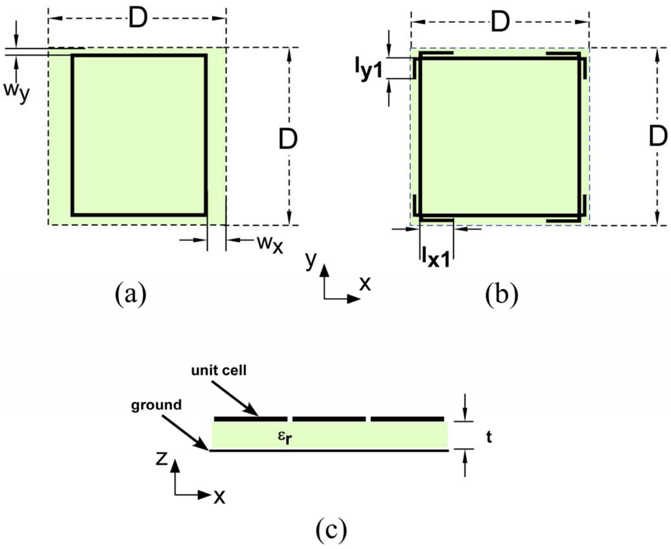

Fig. 1 – Layout of the proposed dual-polarized tags. (a) Unit cell configuration 1 with rectangular loops. (b) Unit cell configuration 2 with square loops loaded with stubs. (c) stackup of the proposed device.

Following this approach, multiple bits can be simply encoded by nesting more than one loop inside the unit cell. For example the reflection coefficient of a periodic artificial impedance surface comprising three rectangular loops having $w_x = 0.23$ mm and $w_y = 0.25$ mm is reported in Fig. 2. By subtracting the obtained slightly shifted responses a differential curve having a high-Q resonant behaviour can be obtained. The differential multi-frequency resonant response is shown in Fig. 3.

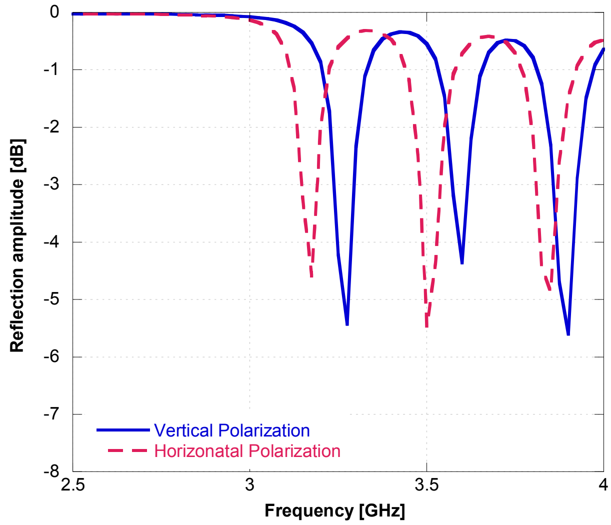

Fig. 2 - Amplitude reflection coefficient for vertical and horizontal polarization of a periodic artificial impedance surface comprising three nested rectangular loops. Geometrical parameters: w_x=0.23 mm and w_y=0.25 mm. The substrate is FR4 with ε_r=4.4-j0.088.The unit cell periodicity *D* is equal to 15 mm.

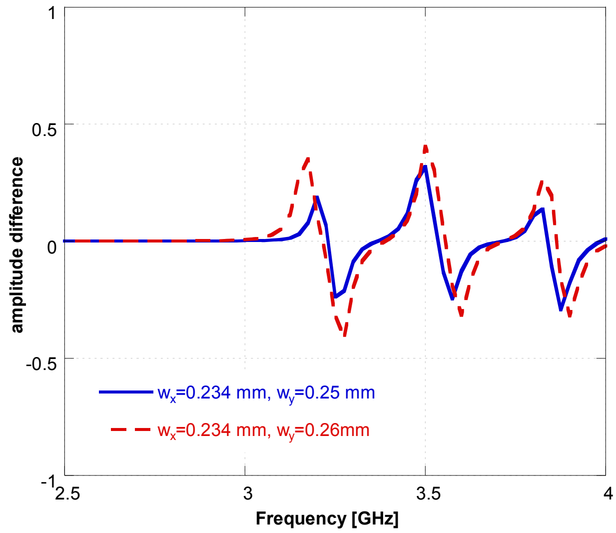

Fig. 3 - Amplitude difference between the reflection coefficients obtained for vertical and horizontal polarization**.** Geometrical parameters: w_x is fixed to 0.23 mm, w_y=0.25mm or w_y=0.26mm.

Another possible layout which allow achieving a high Q-factor differential response is the unit cell reported in Fig. 1b. This is composed by a square loop resonator loaded with slightly different stubs along x and y directions. An example of the frequency response of the described unit cell is shown in Fig. 4. The subtraction of the reflection coefficient obtained by using vertical and horizontal polarizations leads to the curves presented in Fig. 5. It is evident that the stub loaded resonator presents the advantage of a possible frequency shift of the differential resonance. This means that a single loop can be used to encode more than one bit since the presence of a peak in a small frequency bandwidth can be considered a possible encoding state [8]. More precisely, the information coding is not binary but can have a larger base which depends on the number of states of the loop.

In a practical scenario, the periodic impedance surface will be truncated to few unit cells without altering the frequency position of the resonances [9]. This means that the efficient periodic analysis is perfectly valid.

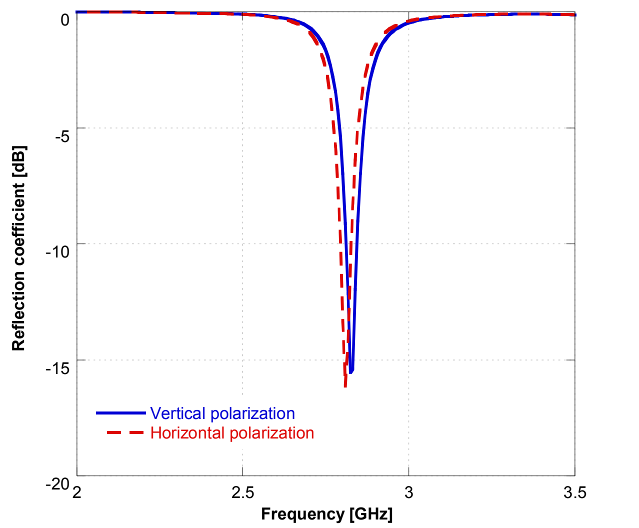

Fig. 4 - Amplitude reflection coefficient at normal incidence for vertical and horizontal polarization of an infinite array of a square loop loaded with different stubs. The substrate is FR4 with ε_r=4.4-j0.088.The unit cell periodicity *D* is equal to 15 mm.

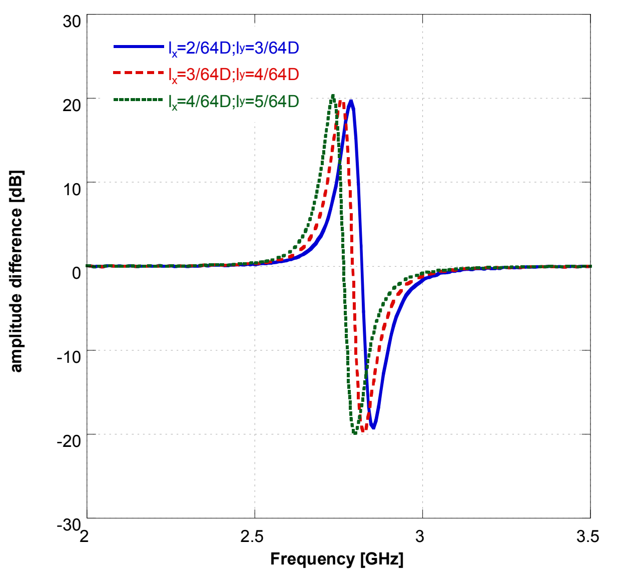

Fig. 5 - Amplitude difference between the reflection coefficients obtained for vertical and horizontal polarization. Geometrical parameters: l_y=l_x+1 with lx equal to 2/64D, 3/64D, 4/64D.

The use of a dual polarized interrogation of asymmetric dual polarized chipless tags can be than employed to avoid the usual unpractical calibration procedure. The logic is that the tag decoding does not consist anymore in a an absolute measurement but in a comparative one. Following the analytical formulation of the problem given in [11], the approach may appear irrelevant since the terms due to the multipath, called O_{vv} and O_{hh}, are not removed after a subtraction. However, received signals can be anti-transformed in the time domain and some effects of the multipath terms can be removed with a time gating. At this point the dual polarization reading turns out to be a strategic approach to further improve the quality of the received signal.

To prove the usefulness of the proposed approach, a 3 bit chipless tag comprising 3 concentric loops has been decoded by using the proposed scheme with the subtraction of vertically and horizontally polarized received signals. Before the subtraction in the frequency domain, the signals are filtered in the time domain. The target result is instead obtained by pre-processing the two signals with the standard calibration procedure using the background subtraction. The results are reported in Fig. 6.

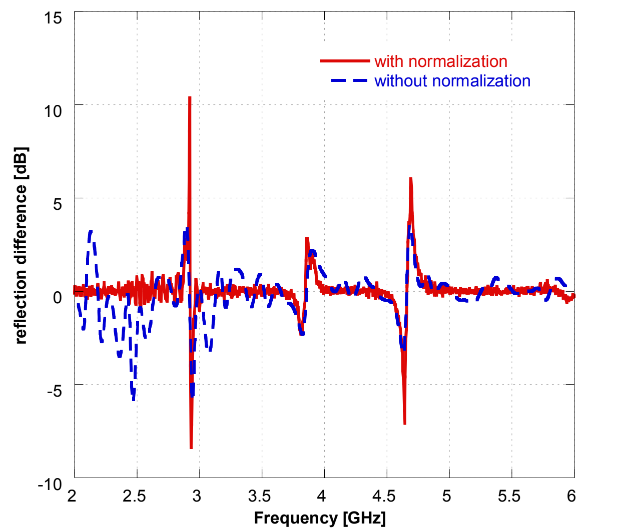

Fig. 6 – Measured amplitude difference between the vertically and horizontally polarized reflection coefficients of a three bits tag. The result obtained by using the standard calibration procedure is compared with the one obtained by avoiding the subtraction of the background.

CONCLUSION

The paper showed that the use of two simultaneous interrogations along two orthogonal planes of a chipless device opens the possibility of a calibration free reading procedure. Experimental results proving the reliability of the proposed approach have been presented.

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