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# Towards Chipless RFID Reading Systems Independent of Tag Orientation

M. Garbati, *Student Member, IEEE*, E. Perret, *Senior Member*, R. Siragusa, C. Halopé

**Abstract**— A reading technique for chipless radio frequency identification (RFID) tags is proposed. It is based on the cross-polarization principle, and unlike classical approach, the introduced technique makes it possible to read classical Chipless tag independently to their orientation. To retrieve the tag identification (ID) the property of short-time Fourier transform (STFT), and a polarization diversity approach are exploited. The former is useful to isolate the tag mode contribution from the total backscattered signal, notably the presence of clutter form surrounding objects. The latter helps to correctly excite the tag resonant scatterers and so to maximize the receiving tag mode energy. The approach has been validated with a laboratory equipment test bench solution, and with a low cost solution.

**Index Terms**— Chipless RFID, cross-polarization, IR-UWB radar, polarization diversity, radiofrequency.

## I. INTRODUCTION

IN chipless radio frequency identification (RFID) the tag does not have any electronic component in its design, and the RF circuit can be directly impressed with industrial printing machine [1]. To compete with barcode technology, the chipless tag needs to be read in real environments with high performance and low cost reader. To obtain such specifications, a cross-polarization reading configuration is mandatory. This configuration ensures high clutter rejection due to the scarce cross-polarization response of practical environments [4]. In a cross-polarization reading, the reader transmits a linear polarized interrogating signal towards the tag and measures the tag response in the perpendicular direction. A chipless tag working in cross-polarization needs to be aligned with the interrogating antennas to maximize the reading performances [3]. In practical application the reader must provide high read rate for automatic identification applications. It is why a cross-polarization reading approach independent of tag orientation is expected.

An orientation independent chipless tag has been introduced in [2]. Anyway, its use in practical applications is limited because the tag is not compliant with cross-polarization reading technique [3]. Till to date, no work is reported on tags which are simultaneously orientation independent and based on cross-polarization approach. Thus, a specific work on the

reader part is needed. A first response was given by the authors in [3]. This paper proposes an evolution of that previous proof of concept. The introduced technique has better performances and also shows faster reading. It was experimented with a test-bench based on laboratory equipment and low cost solution, as proof of concept. The paper is organized as follow: section II describes the introducing approach and shows some simulation results. Section III presents the measurement results, and finally some conclusions are drawn.

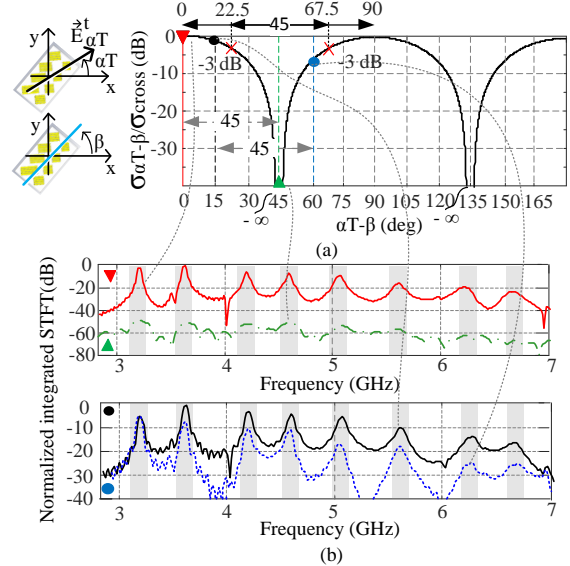


Fig. 1. (a) Variation of the tag TM-CP-RCS with tag ( $\beta$ ) and with the interrogating signal ( $\alpha_T$ ) direction. (b) Simulation of the tag response in frequency domain using a STFT algorithm. For each couple of measurement  $\alpha_T$  is shifted of 45 deg.

## II. TAG ORIENTATION INDEPENDENT APPROACH

### A. Theory

In practical environment, a chipless tag response signal is composed of many components, such as the tag structural mode and the tag mode used to encode the tag identification (ID). In addition, the tag response may have contributions due to clutter, with amplitude that could be higher than the tag mode. Between all the contributions, only the tag mode has a resonant behavior, as so it is easily distinguishable using a short-time Fourier transform (STFT) [4]. In a cross-polarization based chipless RFID system, the reader is able to characterize the tag cross-polarized (CP) Radar Cross Section (RCS). The tag ID is embedded in the tag mode (TM) contribution from the CP-RCS, hereafter just noted TM-CP-

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RCS.

The variation of the TM-CP-RCS versus the angle of observation (transmitting signal direction) has been

Studio Suite 2016. The tag is composed of eight resonators; its first resonant frequency is between 3 and 7 GHz. The simulation result is shown in Fig. 1 (b). The tag ID is coded

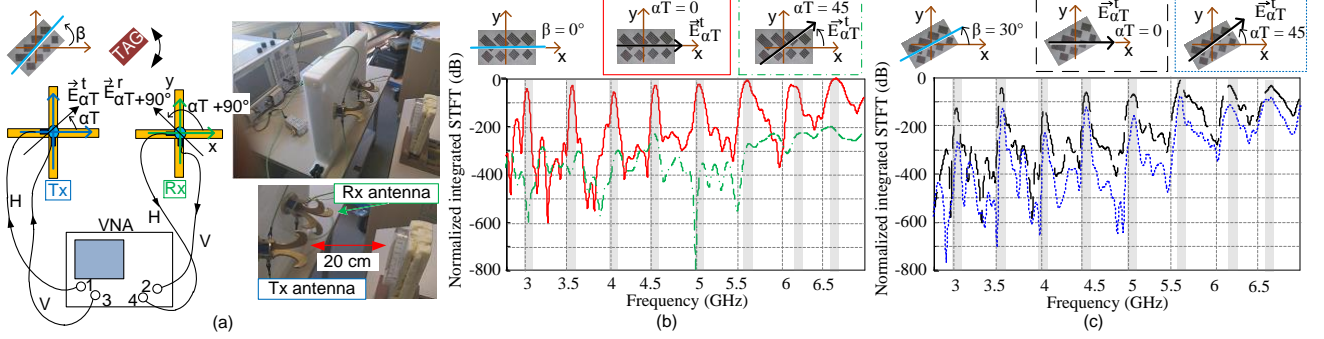


Fig. 2. (a) Reading system based on a 4 port Agilent Technologies N5222A VNA in a practical environment. The tag is placed at 20 cm from the closer point of the antennas. (b) Results of the proposed approach with  $\beta$  equal to 0 deg, and for two values of  $\alpha_T$  (0 deg and 45 deg). (c) Results of the proposed approach with  $\beta$  equal 30 deg, and  $\alpha_T$  of 0 deg and 45 deg.

characterized in [5]:

$$\frac{\sigma_{\alpha_T - \beta}}{\sigma_{Cross}} = |1 - 2\sin(\alpha_T - \beta)|^2. \quad (1)$$

Where  $\alpha_T$  is the angle of the reader interrogation signal, it is referred to the Cartesian coordinate system constructed on the tag plane as shown in Fig. 1 (a).  $\beta$  is the angle of the tag on the same coordinate system,  $\sigma_{Cross}$  is the maximum TM-CP-RCS, and  $\sigma_{\alpha_T - \beta}$  is the actual TM-CP-RCS which depends from  $\alpha_T - \beta$ . Equation (1) is shown in semi-logarithmic scale in Fig. 1 (a), it is a periodic function of period 90 deg, and the tag shows a maximum and a minimum value  $\sigma_{\alpha_T - \beta}$  each 90 deg. The theoretical minimum value of  $\sigma_{\alpha_T - \beta}$  is 0 (-∞ dB), and therefore the tag cannot be read in that condition. This implies a rotation of the tag, or of the incident wave to increase  $\sigma_{\alpha_T - \beta}$ . If we suppose to perform two measurements of the tag with a change of 45 deg for  $\alpha_T$ , then at least one of the two will have an angle  $\alpha_T - \beta$  in-between the range  $\pm 22.5$  deg around one maximum of (1). This is due to the periodicity of (1) and it is shown in Fig. 1 (a). The variation of  $\sigma_{\alpha_T - \beta}$  around  $\pm 22.5$  deg of one maximum of (1) is 3 dB bellow  $\sigma_{\alpha_T - \beta}$ . Thus, with this technique, the tag can be read independently from its orientation.

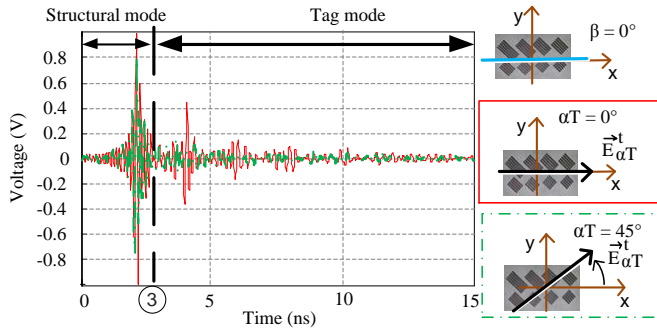


Fig. 3. Tag response in time domain corresponding to the measurement results of Fig. 2 (b) ( $\beta = 0$ ). In red the tag response for  $\alpha_T$  equal to 0 deg, and in dashed green the tag response for  $\alpha_T$  equal to 45 deg.

### B. Simulation Result

The cross-polarized tag used in [3,4] was simulated with CST

based on the positions of the eight resonant frequencies. The tag was interrogated with a linear polarized Electro-Magnetic (EM) plane wave source, with the electric field in the direction defined by  $\alpha_T$ . The tag response was measured in cross-polarization with an electric probe. This model emulates a cross-polarized tag reading system. The tag was simulated for two value of  $\alpha_T$  (0 deg and 45 deg), while the tag position  $\beta$  is varying in such a way to emulate the proposed reading approach. In Fig 1 (b) are shown the simulation results for  $\alpha_T - \beta$  of 0 and 45 deg, and after for  $\alpha_T - \beta$  of 15 deg and 60 deg. They correspond to a tag position  $\beta$  of 0 deg and -15 deg respectively. The STFT was applied to characterize the tag mode in frequency domain that is related to the tag TM-CP-RCS [4]. For real scenarios, the STFT is useful because it is a simple way to isolate the tag ID from all the disturbing parts of the backscattered signal, which can affect the reading.

To avoid a redundancy of information, in Fig. 1 (b) two representative simulation results are shown. In the first couple of measurements ( $\alpha_T - \beta$  of 0 and 45 deg) the tag ID was correctly decoded only when  $\alpha_T - \beta$  is equal to 0, which corresponds to one of the maximum of (1). In the other measurements ( $\alpha_T - \beta$  of 15 and 60 deg) both results show a correct reading. Anyway when  $\alpha_T - \beta$  is equal to 15 deg, more accurate results are obtained because  $\sigma_{\alpha_T - \beta}$  is closer to  $\sigma_{Cross}$ . The proposed approach has been validated by the theory and the simulation. A criterion to select which of the two measurements has to be used to decode the tag ID is given in the next section, along with some practical experimentations.

### III. EXPERIMENTAL RESULT

The proposed approach has been tested in a practical scenario with a vector network analyzer (VNA), and then with the low cost reader proposed in [3].

The VNA was the Agilent Technologies N5222A, and the bench is shown in Fig. 2 (a). The 4 ports of the VNA were used to perform measurements with  $\alpha_T$  equal to 0 deg, and after with  $\alpha_T$  equal to 45 deg. The VNA ports were used in a true-mode differential measurement approach as explained in



- [2] M. A. Islam, Y. Yap, N. Karmakar, and A. K. M. Azad, "Orientation Independent Compact Chipless RFID Tag," in *Proc. IEEE 2012 Int. Conf. on RFID – Techn. and Appl.*, Nice, FR, 2012, pp. 137-141.
- [3] M. Garbati, A. Ramos, R. Siragusa, E. Perret, and C. Halopé, "Chipless RFID reading system independent of polarization," *Proc. IEEE MTT-S Int. Microw. Symp. (IMS)*, San Francisco, CA, 2016, pp. 1-3.
- [4] A. Ramos, E. Perret, O. Rance, S. Tedjini, A. Lázaro, and D. Girbau, "Temporal Separation Detection for Chipless Depolarizing Frequency-Coded RFID," in *IEEE Trans. Microw. Theory Techn.*, vol. 64, no. 7, pp. 2326-2337, July 2016.
- [5] O. Rance, R. Siragusa, P. Lemaître-Auger and E. Perret, "Magnitude Coding Technique," in *RCS Synthesis for Chipless RFID: Theory and Design*, 1th ed., ISTE Press – Elsevier, 2017.