



HAL
open science

Comparison between Cross-polarization and Circular Polarization Interrogation for Robust Chipless RFID Reading

O. Rance, N. Barbot, E. Perret

► **To cite this version:**

O. Rance, N. Barbot, E. Perret. Comparison between Cross-polarization and Circular Polarization Interrogation for Robust Chipless RFID Reading. 2021 51st European Microwave Conference (EuMC), Apr 2022, London, France. pp.668-671, 10.23919/EuMC50147.2022.9784342 . hal-03900066

HAL Id: hal-03900066

<https://hal.science/hal-03900066>

Submitted on 15 Dec 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Comparison between Cross-polarization and Circular Polarization Interrogation for Robust Chipless RFID Reading

O. Rance^{#1}, N. Barbot^{#2}, E. Perret^{#*3}

[#]Univ. Grenoble Alpes, Grenoble INP, LCIS, 26000 Valence, France

^{*}Institut Universitaire de France, 75005 Paris, France

{¹olivier.rance, ²nicolas.barbot, ³etienne.perret}@lcis.grenoble-inp.fr

Abstract — Circular polarization for chipless tag interrogation has recently been presented as an improvement over the conventional cross-polarization method as it is supposed to be both orientation-independent and able to isolate the tag from its environment. In this article, we make a systematic comparison between the two approaches. We show, from both theory and measurements, that for the circular polarization approach, the assumptions of orientation independence and isolation are valid only for very specific and non-realistic environments. A new tag has been used for the characterization. It can be manufactured by hand in less than five minutes at negligible cost and yet has performances comparable to optimized tags, making it ideal for rapid prototyping.

Keywords — Radar Cross Section, Circular polarization, chipless RFID, polarimetric scattering matrix.

I. INTRODUCTION

The radar signature of a chipless RFID tag is generally very small compared to that of the surrounding objects. A classical technique [1] to separate these two contributions is the use of a depolarizing tag (dipoles oriented at 45°) combined with a cross-polarization interrogation, as shown in Fig. 1a. This method is considered the most robust at present but requires knowledge of the orientation of the tag.

One possible improvement path is the use of a circularly polarized (CP) wave for interrogation (Fig. 1b), which would make the reading independent of orientation. This approach has been presented in two recent studies, but both have limitations. In [2], the authors show rotational invariance in measurement for only three different angles and do not present a theory to support this assertion. Moreover, they do not show the impact of the environment in measure. In [3], the authors show the rotational invariance only in simulation (in the absence of environment) and the robustness of reading is shown in measurement only for a single environment consisting of a square metal plate. That environment, despite having a high RCS in co-polarization, will be proven to be a favorable case.

In this paper, we will first establish the theoretical link between the two approaches, which will allow us to rigorously justify the invariance and isolation hypotheses as well as their limits. These two hypotheses will be tested in measurement.

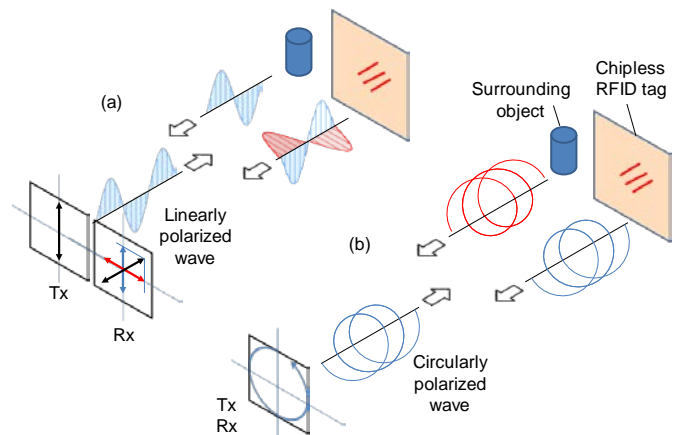


Fig. 1. (a) Cross-polarization interrogation technique [1]. The PSM of the tag has a non-zero cross-component S_{vh} , which is not the case for classical objects. (b) Circular polarization approach [2-3]. The PSM of the tag has a non-zero component with same handedness (e.g. S_{ll}), which is not the case for classical objects.

II. THEORY

A very powerful tool for the analysis of scatterers is the polarimetric scattering matrix (PSM) [4] which was introduced during the early development of radar. The PSM relates the incident and reflected electric field at the target, component by component, and makes it possible to calculate analytically the dependence on the orientation θ (angle with respect to vertical) using [4]:

$$\mathcal{S}(\theta) = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \cdot \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}. \quad (1)$$

The PSM can be defined for either linear or circular polarization (denoted \mathcal{S} and \mathcal{S}_c respectively) and the relation between the two is given by a simple change of basis [4]:

$$\begin{bmatrix} S_{ll} & S_{rl} \\ S_{lr} & S_{rr} \end{bmatrix} = \begin{bmatrix} 1 & -j \\ 1 & j \end{bmatrix} \cdot \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} 1 & 1 \\ -j & j \end{bmatrix}, \quad (2)$$

Table 1. Polarimetric scattering matrix of classical targets as a function of the orientation θ for both linear and circular polarizations.

	Scatterer type	$S(0)$	$S(\theta)$ calculated using (1)	$S_c(\theta)$ calculated using (1) and (2)
R1	Dipole like scatterer	$a \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$	$a \begin{bmatrix} \cos^2 \theta & -\sin \theta \cos \theta \\ -\sin \theta \cos \theta & \sin^2 \theta \end{bmatrix}$	$\frac{a}{2} \begin{bmatrix} e^{j2\theta} & 1 \\ 1 & e^{-j2\theta} \end{bmatrix}$
R2	Specular reflexion (ideal environment)	$a \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	$a \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	$a \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$
R3	Non specular reflexion (realistic environment)	$\begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix}$	$\begin{bmatrix} a \cos^2 \theta + b \sin^2 \theta & (b-a) \sin \theta \cos \theta \\ (b-a) \sin \theta \cos \theta & b \cos^2 \theta + a \sin^2 \theta \end{bmatrix}$	$\begin{bmatrix} (a-b)e^{j2\theta} & a+b \\ a+b & (a-b)e^{-j2\theta} \end{bmatrix}$

where l and r stand for lefthand and righthand polarizations and v and h stand for vertical and horizontal.

Table 1 gives the PSM of reference targets as a function of the orientation θ for both linear and circular polarizations calculated from (1) and (2). Before analyzing each scatterer individually, it is worth noting that the components of S exhibit dependence on θ in both magnitude and phase, while only the phase of the components of S_c is influenced by θ . The total backscattered E-field is generally a complex sum between a tag for which θ can be varied and a static environment (with static orientation θ_0):

$$S_c^{\text{tot}}(\theta) = S_c^{\text{tag}}(\theta) + S_c^{\text{env}}(\theta_0) \quad (3)$$

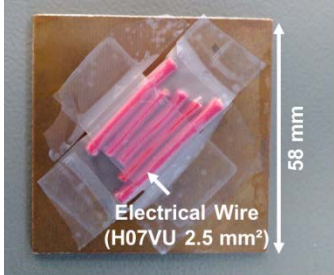
And it becomes evident that the magnitude of the total signal varies with θ due to the possible recombination of the respective phases. The hypothesis of rotational invariance is therefore not valid for CP in presence of an environment.

The first row (R1) of table 1 presents the PSM of a dipole. We see that, as expected by both techniques, the tag has a maximum cross-polarization S_{vh} for $\theta = 45^\circ$ and also has a non-zero S_{ll} component. We now consider the second row R2 which corresponds to an ideal environment for which the approximation of optical reflection is valid. Note that the same scattering matrix is obtained for a planar target having n -fold symmetry with $n > 2$ [5], which is the case for the environment chosen in [3]. In this case we see that the components S_{vh} and S_{ll} are both null, so that it should not introduce any perturbations for the reading techniques presented in Fig. 1. However in most cases it is not possible to approximate the environment using R2. A more realistic environment can be represented with the case $S_{vv} \neq S_{hh}$ which corresponds to R3. In this case, S_{vh} and S_{ll} are not zero, implying that the environment disturbs the measurement of the tag for both techniques. However, the environment is predominantly composed of vertical or horizontal objects, so that it is usually possible to consider that $\theta_0 = 0^\circ$ or $\theta_0 = 90^\circ$, which leads to a cancellation of S but not S_c . The perturbation introduced by the environment is thus usually weak for the cross-polarization approach, while it remains important for the circular polarization. The special case $S_{vv} = S_{hh}$ represents an important operational constraint and is rarely encountered in practice.

III. MEASUREMENTS

A. Tag and Measurement Setup

It is not necessary to precisely control the resonance frequency of the dipoles to characterize the reading method. We therefore propose a new rapid prototyping method which simply consists in cutting sections of electrical wires (H07VU 2.5 mm²) which are then taped on a square ground plane as shown in Fig. 2. The insulating PVC sheath of the electrical



	F(GHz)	Q	S_{21} (dB)
Res1	3.06	87	-40.2
Res2	3.59	89	-41.8
Res3	4.1	117	-43.1
Res4	4.50	107	-44.5
Res5	4.96	90	-43.1
[1]	3.58	79	-41.5

Fig. 2. Picture of the tag made by taping sections of electrical wires to a ground plane. This rapid prototyping method gives comparable performances to optimized tags realized by chemical etching on RF materials [1].

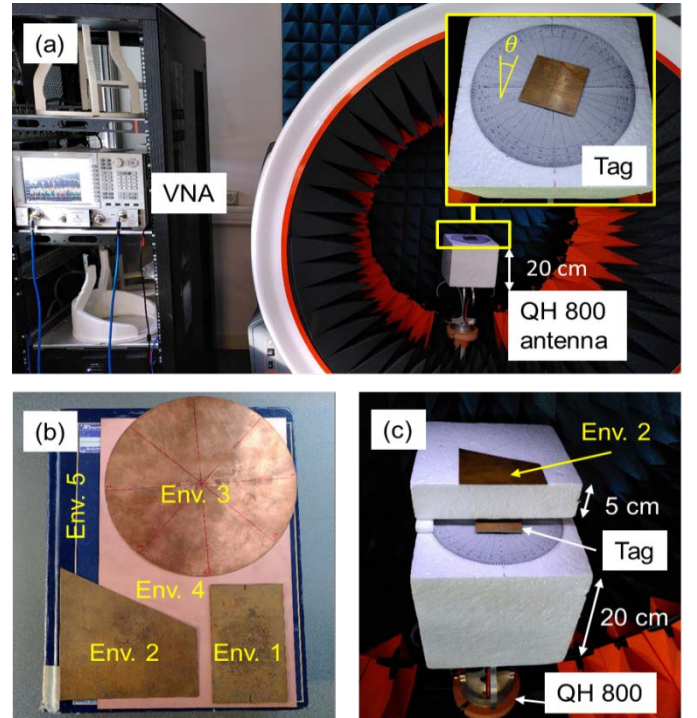


Fig. 3. (a) Picture of the measurement setup. Monostatic measurement in semi-anechoic environment. (b) Different surrounding scatterers used for environment. The scatterers are numbered by increasing RCS level. (c) Surrounding scatterer positioned 5 cm behind the tag.

wire ensures a good spacing between the different resonators as well as with the ground plane. This configuration, which does not use any specific RF material, makes it possible to produce microstrip resonators in less than 5 min with almost negligible cost and good coding density. The resonators made in this way (Fig. 2) have a comparable RCS and a selectivity that is even higher than tags that have been optimized and realized by chemical etching on RF materials [1]. The scattering matrix of the resonators is given by R1 in table 1.

The measurement setup is shown in Fig. 3a. We used the same QH 800 antenna with ports V and H connected either directly to the VNA (Agilent Technologies PNA 5222A) for cross polarization measurement or to a quadrature hybrid coupler (QH0226) for circular polarization measurement. For the CP configuration, we obtain an axial ratio inferior to 1.5 dB and a cross-polarization ratio superior to 21 dB. The tag is placed 20 cm from the antennas in a semi-anechoic environment (modified starlab).

B. Effect of the Orientation

The first series of measurement shows the influence of orientation on the tag signature. The tag, whose dipoles are initially oriented at 45° in order to maximize the cross-polarization components, is rotated from 0° to 90° by steps of

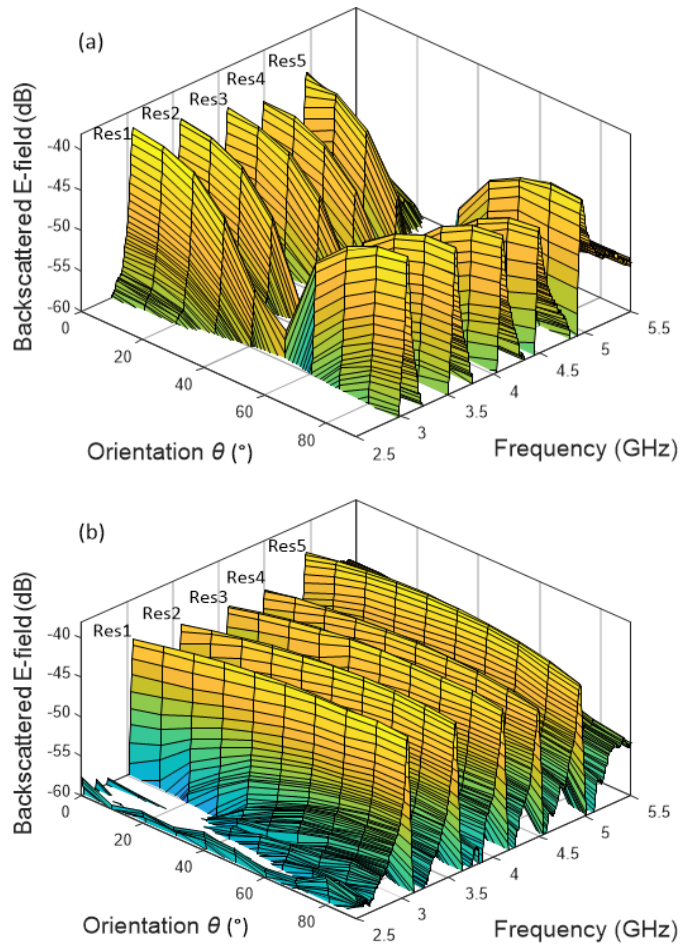


Fig. 4. Measurement results of the tag signature as a function of orientation θ for (a) linear and (b) circular polarization.

10° . The orientation of the tag is manually modified with a precision of approximately 2° . For linear polarization (Fig. 4a), a 45° signal cancellation is observed for all dipoles, which is theoretically expected according to (1). For the circular polarization (Fig. 4b), there is no cancellation and the signal appears to be relatively independent of the angle (a maximum variation of 3.8 dB is observed for the Res2 for a 25 dB peak). It should be noted, however, that the ground plane of the tag has been integrated into the reference measurement and subtracted from the tag measurement in Fig. 4. If not, the total backscattered signal is the complex sum between the broadband signal of the ground plane and the resonant signal of the microstrip dipoles (3). In such a case, the resonances are observable whatever the angle but sometimes in the form of a peak and sometimes in the form of a dip due to phase recombination.

C. Effect of the Environment

For the analysis of the influence of the environment, we consider five different environments (Fig. 3b) which are positioned 5 cm behind the tag (Fig 3c). For linear polarization (Fig. 5a), the environment has only a limited influence on the tag signature with a maximum variation compared to the tag alone of 2 dB on Res4 for Env. 2, which is the one with the

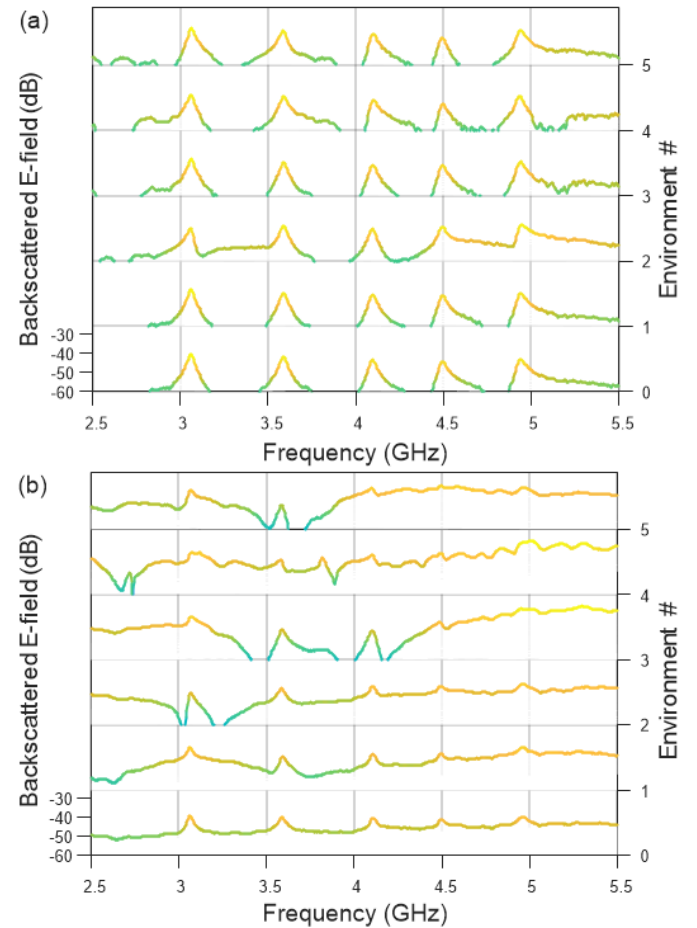


Fig. 5. Measurement results of the tag in presence of different environments for (a) linear and (b) circular polarization. Env. 0 stands for the tag alone.

largest cross-polarization magnitude. On the other hand, it is clear that the signature of the tag is strongly influenced by the environment for circular polarization (Fig. 5b). Although perturbed, the tag identifier remains readable for environments 1 and 2. For env. 3 to 5, which have a higher RCS in co-polarization, the signature can no longer be decoded.

IV. CONCLUSION

In this paper, we have tested the hypotheses of rotational invariance and isolation for the circular polarization reading method. The method can be considered invariant by rotation for a tag measured in semi-anechoic condition and a well-chosen ground plane shape (R2 of table 1) but not for real environment. It was also found that the method cannot be considered as an improvement of [1] in terms of reading robustness because it is highly impacted by environment.

ACKNOWLEDGMENT

This work is funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant No 772539, SCATTERERID).

REFERENCES

- [1] A. Vena, E. Perret, and S. Tedjni, 'A depolarizing chipless RFID tag for robust detection and its FCC compliant UWB reading system', *IEEE Trans. Microw. Theory Tech.*, vol. 61, no. 8, pp. 2982–2994, Aug. 2013.
- [2] M. Martinez and D. van der Weide, 'Circular polarization on depolarizing chipless RFID tags', in *2016 IEEE Radio and Wireless Symposium (RWS)*, pp. 145–147, Jan. 2016.
- [3] S. Genovesi, F. Costa, F. A. Dicandia, M. Borgese, and G. Manara, 'Orientation-insensitive and normalization-free reading chipless RFID system based on circular polarization interrogation', *IEEE Trans. Antennas Propag.*, vol. 68, no. 3, pp. 2370–2378, Mar. 2020.
- [4] E. F. Knott, J. F. Schaeffer, and M. T. Tulley, *Radar Cross Sections*, 2nd edition. Raleigh, NC: SciTech Publishing Inc, 2004.
- [5] A. Mackay, 'Proof of polarisation independence and nonexistence of crosspolar terms for targets presenting n-fold ($n > 2$) rotational symmetry with special reference to frequency-selective surfaces', *Electron. Lett.*, vol. 25, no. 24, pp. 1624–1625, Nov. 1989.