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# Reading UHF RFID tags inside passenger vehicles

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***ABSTRACT:*** *Among many types of wireless links, RFID presents the great advantage of using batteryless devices. Thus, applying in a maintenance and repair system, it is the cheapest, easiest to install non-intrusive solution, well suited for equipment of classical cars. This paper gives quantitative results stemming from an experimental and numerical study and allowing to estimate the limitation of passive UHF RFID tags for implementation of this solution. The gained information defines in particular the sensitivity threshold that should be reached by purely passive tags in order to run in this semi-confined geometrical configuration.*

***KEYWORDS -*** *embedded tags, EPC C1G2, in-out-car, low speed, readability, UHF RFID*

## I. INTRODUCTION

RFID (Radio Frequency IDentification) allows you to retrieve information contained in a tag from an RFID reader through electromagnetic waves. The performance of such a system is related to reading tags, data transfer between the reader and the tag, cost and sensitivity in relation to the environment in which on the spot [1-2]. The communication with a transponder located close behind the windscreen of a coach is described by many papers [3-7]. Indeed, this solution is currently used on the highway as a hand-free toll. The study with a cargo car presented in [8] show that tags inside a cargo van with a reader located outside is feasible but not easy. The aim of this paper is to develop the knowledge in using UHF RFID technology in more confined tourism car context.

## II. EXPERIMENTAL PROTOCOL

All measurements have been carried out using a sedan car shown in Fig. 1. A first step has consisted in placing various types of EPC global C1G2 tags [9] inside the car at locations like sun-visor (SV), lateral windows (LW), dashboard (DB). The case of a tag located on the top of a cardboard 50cm high above the ground without the car (WC) has been also considered and will be used as a reference non confined case. In the rest of the paper, each tag is indicated by a letter as defined in Fig. 2. Tag A is a UPM Raflatac frog dual dipole tag, B is a UPM Raflatac Dogbone tag and M is a Confidex Ironside on-metal tag. The reader is a Intelleflex equipped with dual patch antenna circularly polarized shown in figure 1. The first set of measurements consisted in moving the reader antenna away from the vehicle from 1m until 4 meter along an axis orthogonal to the vehicle axis in order to determine the maximum reading distance for a fixed position of the car. The reader is located face to face with the front window of the passenger side. No one is seated inside the car. Then, the reader at a fixed location 1.15m height on a tripod and moving the car at slow speeds in accordance with a return back into a garage. Height of the reader antenna is another interesting parameter which has been studied. Although it is intuitively better to place the reader antenna at the level of the windows, the case of an antenna pointed toward the metallic part of a door is also considered. Indeed, a future work will study the case of RFID sensors located close to the engine under the bonnet.

Fig.1. View of the experiment setup

Fig. 2. View of the 3 types of passive tags

## III. RESULT AND ANALYSIS

The results when the reader antenna move away from the vehicle from 1m until 4 meter along an axis orthogonal to the vehicle axis fixed position of the car have been reported in Fig. 3. The bar graph shows the reading distance for each type of tag and each location within the car. The reference case WC exhibits a maximum reading distance of around 3 m, less than the theoretical maximum distance of 9 m because of the proximity of the ground. Moreover, the reading distance is weaker with the M tag according to the missing requisite conductive reflective sheet. The maximum reading distance of the reference case is regularly reached when the tag is located on the sun-visor. It is clearly shown that the distance is greater than 1 m for each location, except for the M tag. In the following of the work, the distance between the car and the reading antenna is fixed to 1 m. It has to be pointed out that this distance should satisfy the practical requirements. Indeed, the distance must be high enough for avoiding destroying the wing mirror when moving through the RFID gate placed at the entrance of the garage.

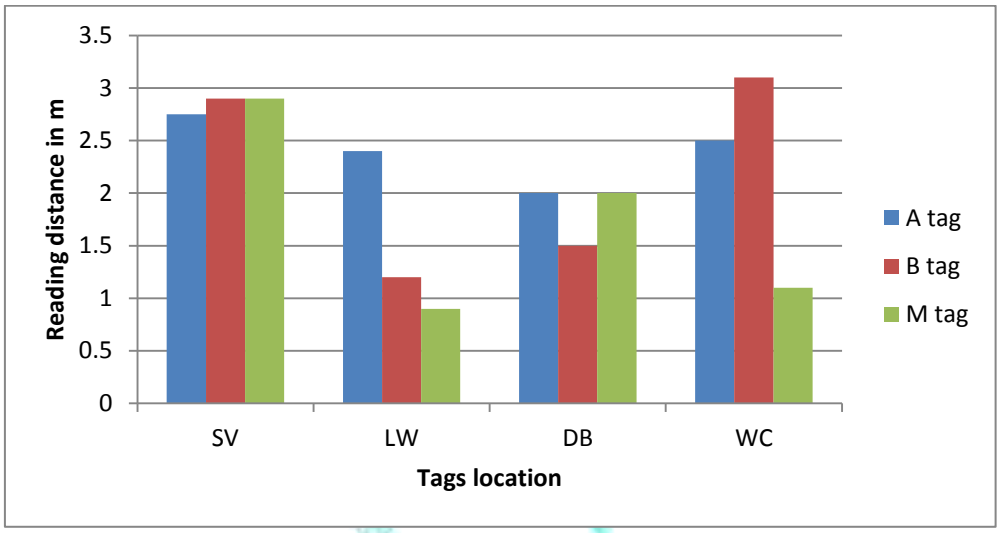



Fig. 3. Reading distance for various types of tags and locations within the car.

The following experiments have been carried out maintaining the reader at a fixed location 1.15m height on a tripod and moving the car at slow speeds in accordance with a return back into a garage. The B tag has been selected because of its small size and its sensitivity to only one linear polarization, although the reading performances of the A tag are globally better. Fig. 4 shows the various locations of a set of 4 tags placed within the car. Tags have been placed at the foot of and above the rear seats and on the dashboard, at the foot of, above and under front seats. Results are shown in Table I where a successful reading is indicated with a circle symbol whereas an unsuccessful reading is indicated by a cross symbol. The lines of tags 1 and 2 are located on the passenger side (right side) and the lines of tags 3 and 4 are located on the driver side (left side). The better performances are reached on the dashboard and above the rear seat. The former case is well-known because similar to the hand free toll system. The latter case shows that a reader should easily read passive tags placed above the rear seats when any passengers are sitting. One should take advantage of this phenomenon for the detection of presence of passenger because their body will cut off the communication between a tag and a reader. Indeed, it is clearly shown that the presence of the driver and a passenger sitting on the front seats disturb the wireless communication.

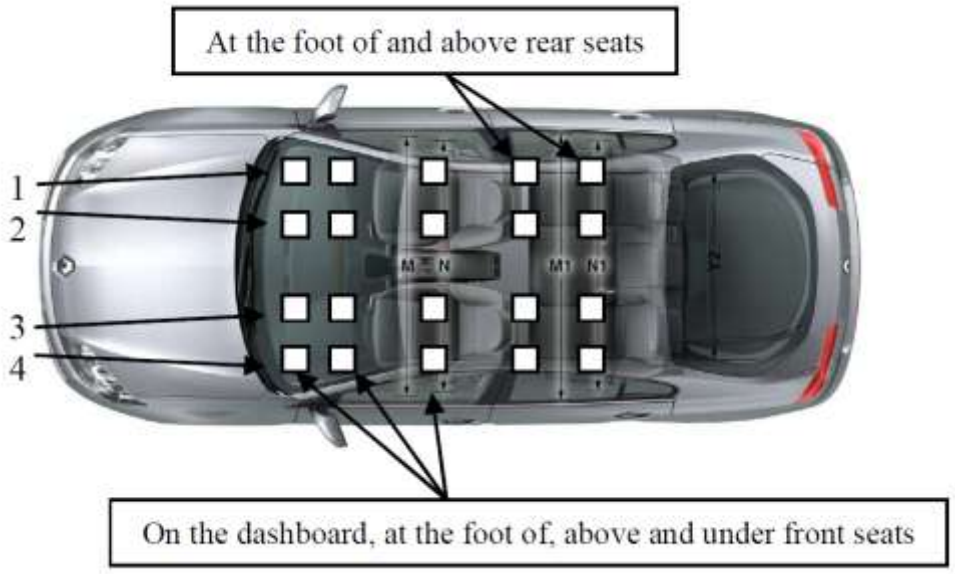



Fig. 4. Different locations of the tags : on dashboard, at the foot, above and under front and rear seats.

TABLE I

SUCCESSFUL READING IN VARIOUS LOCATIONS
WITH A DRIVER ON THE LEFT FRONT SEAT SITTING

| **Tag line locations** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| On the dashboard | o | o | o | o |
| above the front seats without any passenger | x | x | o | o |
| above the front seats with a passenger | x | x | x | x |
| Under front seats | x | x | o | x |
| At the foot of front seats | x | x | o | o |
| Above rear seats | o | o | o | o |
| At the foot of rear seats | o | o | o | x |

The case of the B tag placed above the rear seats has been considered only for studying the influence of the car speed. The driver is alone in the car. Two locations of the reader on each side of the car have been tested. The results are given in Table II where DS and PS indicate respectively Driver Side and Passenger Side for 3 values of the speed: 10km/h, 20km/h and 30km/h. Experiments have been repeated 5 times in order to better estimate the reading successful rate. More tests should be better but overly time consuming.

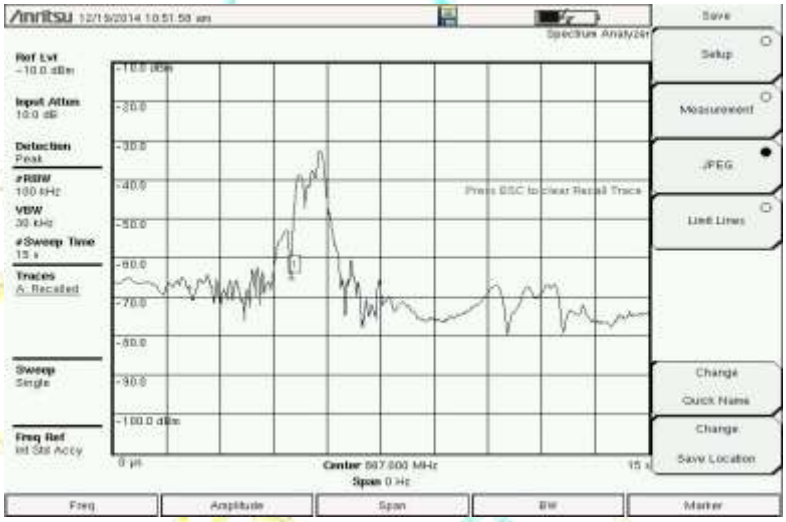
TABLE II

SUCCESSFUL READING ABOVE REAR SEATS
FOR DIFFERENT CAR SPEEDS

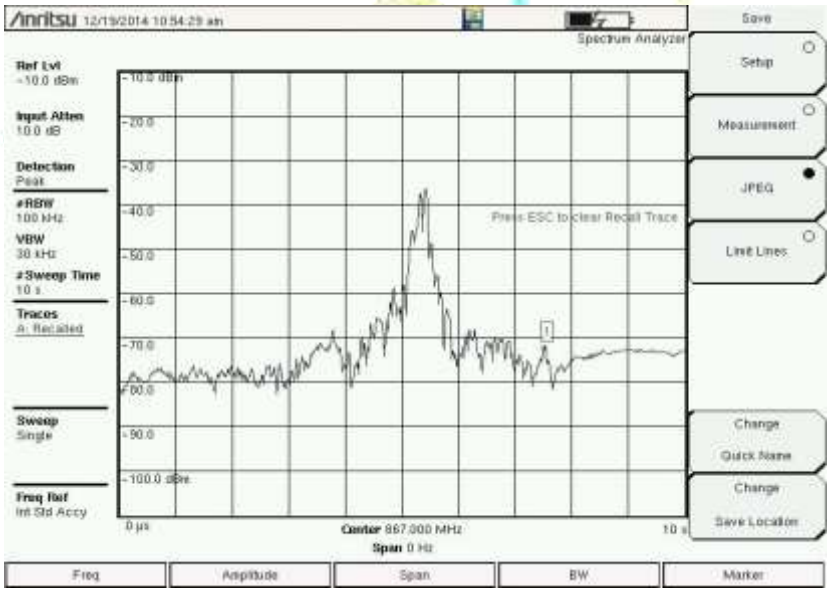
| **Tag line** | **1** | | **2** | | **3** | | **4** | |
|---|---|---|---|---|---|---|---|---|
| **Car speed** | **DS** | **PS** | **DS** | **PS** | **DS** | **PS** | **DS** | **PS** |
| **10km/h** | o | o | o | o | o | o | o | o |
| | o | o | o | o | o | o | o | o |
| | o | o | o | o | o | o | o | o |
| | o | o | o | o | o | o | o | o |
| | o | o | o | o | o | o | o | o |
| **20km/h** | o | o | o | x | o | o | o | o |
| | o | o | o | x | x | x | x | o |
| | x | o | o | x | o | x | o | o |
| | o | o | o | x | x | x | x | o |
| | o | o | o | o | x | x | x | o |
| **30km/h** | o | o | o | x | o | o | o | o |
| | x | o | x | x | x | x | x | x |
| | o | o | o | x | o | o | o | o |
| | o | o | x | x | o | o | o | o |
| | x | x | x | x | o | o | x | x |

It is observed that the reading tag performances decrease substantially when the speed increases. In order to better understand the phenomenon, supplementary measurements have been done with a Continuous wave source (CW). The field strength is received by a horizontal monopole antenna mounted on a spectrum analyzer at the foot of the front passenger seat as shown in Fig.5. According to the value of the transmitted power, cable attenuation and antenna gain, the receiving threshold corresponding to a -15dBm tag sensitivity is equal to -50dBm. The results reported in Fig .5-b- and Fig .5-c- clearly demonstrate that the signal

-a- Location of the spectrum analyzer with antenna




-b- Signal strength received at 10km/h




-c- Signal strength received at 10km/h

Fig. 5. Measurement of the field strength of the field in CW for two values of the car speed : -b – 10km/h and –c- 20km/h.

Height of the reader antenna is another interesting parameter which has been studied. Although it is intuitively better to place the reader antenna at the level of the windows, the case of an antenna pointed toward the metallic part of a door is also considered. Indeed, a future work will study the case of RFID sensors located close to the engine under the bonnet. The successful rate has been putted in Table III where the differences between both heights of the antenna are clearly emphasized. Those binary results are more detailed in the part III of this paper in order to assess the margin existing between the reading threshold and the non-reading one. 100% in front of the the window part of the door have been read.

TABLE III

SUCCESSFUL READING ABOVE REAR SEATS
FOR DIFFERENT READER ANTENNA HEIGHTS AT 10 KM/H

| **Tag line** | **1** | | **2** | | **3** | | **4** | |
|---|---|---|---|---|---|---|---|---|
| **Car heights** | **DS** | **PS** | **DS** | **PS** | **DS** | **PS** | **DS** | **PS** |
| **In front of the metallic part of the door** | o<br>x<br>o<br>o<br>x | o<br>o<br>o<br>o<br>x | x<br>x<br>x<br>x<br>x | x<br>o<br>x<br>x<br>o | x<br>o<br>o<br>x<br>o | o<br>o<br>o<br>o<br>o | x<br>x<br>x<br>x<br>x | o<br>o<br>o<br>o<br>o |
| **In front of the window part of the door** | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o | o<br>o<br>o<br>o<br>o |

## IV. CONCLUSION

The study presents the use of EPC C1G2 passive tags in a passenger vehicle with a reader located outside. First, different tags used (A is UPM Raflatac frog dual dipole tag, B is a UPM Raflatac Dogbone tag and M is a Confidex Ironside on-metal tag) are placed in different places in the vehicle. Thus, for each tag, we look the reading rate at the different places when the vehicle is stationary. Also the height of the reader varie. To study the influence of the vehicle on the reading of tags, we use the tag B. The results thus obtained show that the faster the speed at the passage in front of the reader less obvious will be the read of the tag. We also see that the position of the reader (facing the window or facing the body) will influence the reading. The number of tags being limited. The study is continuing with a numerical simulation model based on Geometrical optics in order to refine the reading zones in a passenger vehicle. The approach is based on the Geometrical Optics theory improved for the diffraction effects by using equivalent fictitious physical parameters defined by a calibration preliminary step. This original method is described in [10]

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