

# Using Radio Frequency Identification Technology to Track Individual Wine Bottles

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**Abstract:** Radio Frequency Identification (RFID) technology has been tested and it is now proposed to be used in applications as food traceability, instead of the traditional barcode, as that could get advantages of its inherent characteristics: automatic management and distance readability. Among food industries, wine production represents an added value sector and so it would be a target to implement RFID. Wine bottles present some problems to the radio propagation, as liquids are not electromagnetically friend materials. Thus, a large radio electric measurement campaign has been performed in order to deal with the possible mismatches in using this technology to trace wine bottles from the wine cellars to the final consumer. The performance of different RFID tag models, as well as the effect of the wine content within the bottle, is analysed along the paper, trying to identify the better technological solution. The tests indicate that the use of RFID methods would be suitable to allow the consumer to obtain complete traceability information from each wine bottle, and the producer to track its products. The proposal opens the door to new possibilities in the relationship between consumer and producer, by demonstrating the possibility of using a new technology in a traditional market.

## 1 INTRODUCTION

Some years ago, wine consumers hardly taste products far away their own country, and even their own region. In such circumstances, people were confident of the product they bought. Perhaps they personally met the producers, or some people working at any production stage that could significantly inform about the quality of the wine they purchased. However, nowadays the market is far from being local, and it has become global. This fact is, indeed, an advantage. Thousands of different wines are available at most of the markets in the World, both traditional or on line. But that carries a lack in the confidence, which only could be solved by traceability technique proposals. Now, most of the food industries have implemented traceability procedures that assure the quality at the different business steps. But the consumer hardly receives such information. He only has access to the short data on the label: the name of the wine, some origin information, perhaps grape varietals, and sometimes other nutritional figures.

The use of radio frequency identification (RFID) technologies combined with transnational data bases

and, possibly, web services would be a technical solution to both troubles; to allow a complete traceability from producer to consumer, known as “from farm to fork”, but also to make this information available for the consumer. The final proposal is to provide each bottle with a RFID tag that univocally identifies it, and to use this tag to trace the bottle from the winery to the consumer, passing through the storage stage, transportation, distribution, shopping,... controlling at each moment its location and conservation conditions. A summary of this information could be available for the consumer by reading the RFID tag with his smartphone and accessing the web service to read the data in the own phone. This futuristic scenario is technologically possible, as tested by European Project RFID-F2F (RFID-F2F web page, 2011) (Cuiñas et al., 2011); (Catarinucci et al., 2011), but some electromagnetic restrictions could limit the extension of the application.

The RFID technology (ISO/IEC 18000) is now mature for large developments. The basic idea of such systems could be paralleled to the bar codes. Each product to be traced must be identified by a RFID tag, which aspect is like a label that could

even be printed but it also contains a small electronic circuit. The bar code reader would be replaced by a RFID interrogator, which transmits radio frequency signals that the tags identify as questions. Once a tag receives a question, it transmits the identification information it has previously recorded. The tags do not need to be supplied by external power sources, as they harvest the energy received with the question to generate the transmitted answer.

However, there are some limitations that are inherent to the radio propagation characteristics. The liquids and metallic elements are not friend materials for electromagnetic fields radiation (Zhang et al., 2009); (Hasar, 2009); (Wang and Afsar, 2003). This unfriendly environment represents a constraint in the extension of RFID and other electromagnetism-based technologies. In fact, the aim of this paper is to analyse the use of RFID in tracking wine bottles, and to study the technical viability of such application, trying to overpass the constraints induced by the elements we are managing.

UHF technology has been preferred to HF in order to develop a RFID system EPCglobal compliant. In addition recent works reveal that passive UHF RFID systems provide many advantages over HF ones (Uysal et al., 2008). Something which affects the wine supply chain in particular is the fact that some steps require far field interrogation, where HF tags cannot be used as they do not work properly (Cuiñas et al., 2011).

At item-level tagging, several UHF RFID solutions have been proposed, some of them based in the use of general purpose UHF far field (FF) tags and other in near field (NF) ones (Catarinucci et al., 2010). UHF NF RFID technology is used when materials containing liquids and metals are involved, as they allow mitigating performance degradation due to the absorbance of RF energy. However, it could be not suitable in steps where the distance between the RFID tag and the antenna is large or several RFID tags must be read simultaneously (De Blasi et al, 2009). Moreover, recent experimental studies have shown that FF passive UHF RFID tags are able to provide higher performance in critical conditions than NF ones also in an item-level traceability system when using NF RFID antennas (De Blasi et al., 2009) (Catarinucci et al., 2010).

In our approach we decided to use FF UHF RFID tags. The intention is to find a tag that could be used in the whole supply chain. Thus, a large experimental research has been done.

## 2 TEST SET AND PROCEDURE

The study of the viability of the bottle tracking system is proposed to be done by means of a large experimental measurement campaign. The description of the experiments is the objective of this section.

### 2.1 Equipment and Materials

The main equipment used was a RFID interrogator model ALR 9900 from Alien Corporation (Alien, 2012a). Although various researchers have proposed specific antenna designs for readers (Fan et al., 2007); (Mahmoud, 2010), the authors decided to provide their reader with a cush-craft antenna Alien ALR-8611-AC (Alien, 2009), as the equipment would be directly implemented. The transmitter/receiver system operates in the UHF band, at 866 MHz.

During the tests, up to eight tag models were involved, each one at a time, to avoid interference problems (Lazaro et al., 2009). The objective was to determine the design that best adapts the electromagnetic behaviour of the bottle. This model would be proposed as the most effective for the application. The tested tags were manufactured by UPM (UPM, 2010a); (UPM, 2010b); (UPM, 2010c); (UPM 2008); or by Alien Corporation (Alien, 2012b); (Alien, 2012c); (Alien, 2012d); (Alien, 2012e) and their shapes are represented in figures 1 and 2, respectively.

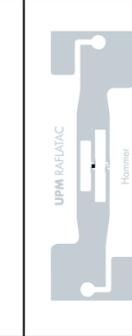
			
UPM Dogbone Paper Tag 97 x 27 mm	UPM Shortdipole Paper Tag 97 x 15mm	UPM Hammer Paper Tag 80 x 25mm	UPM Web Paper Tag 54 x 34mm

Figure 1: RFID tags manufactured by UPM.

The tags were attached to the bottle with vertical orientation in order to minimize performance loss due to antenna curving. As we try to provide information about a traceability system with massive application, it would be out of scope the needing of a

particular RFID tag design, as the individual cost of these advanced models is unaffordable for wine producers.

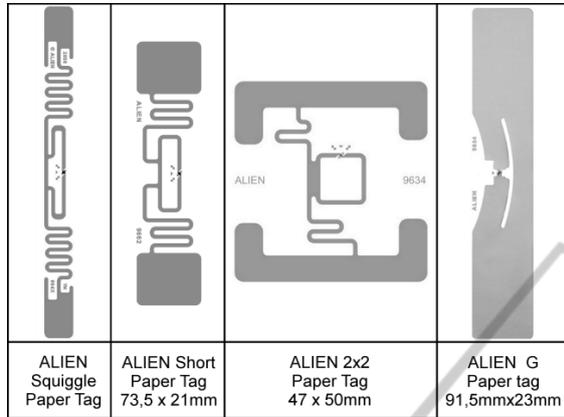


Figure 2: RFID tags manufactured by Alien Corporation.

The object to be tracked is, of course, also important. And the variety of wine bottle designs, with slight differences among them, is really large. So, we have used four different 75 cl wine bottles. And we tested two red wine bottles and two white wines, all produced at well-known Spanish denominations of origin. The bottles were labelled from 1 to 4, and their dimensions are summarized in table 1. All of them are Bordeaux shape design, except number 1 that is like Burgundy shape.

Table 1: Bottle dimensions.

bottle	wine	complete bottle		neck	
		height (cm)	base diameter (cm)	length (cm)	diameter (cm)
1	white	30.0	8.3	10.5	2.8
2	red	30.0	7.5	8.5	3.0
3	white	32.0	7.3	8.5	2.9
4	red	31.5	7.4	8.4	2.9

## 2.2 Procedure

The measurement campaign has been conducted inside an anechoic chamber. Thus, when the RFID interrogator reads the tag on the bottle, the received signal comes surely from the tag, and not from outside or after reflections on the room limits. Such a facility guarantees the validity of the presented results.

Each tagged bottle was placed in a fixed location in the centre of the chamber, on a metallic platform, as it would be placed in most of the industrial processes. The RFID antenna, connected to the interrogator, was moved around the bottle axis,

following a circular path. The distance from the antenna to the rotation axis was 60 cm, and the antenna was pointed to the bottle with an inclination of  $19^\circ$  with respect to the vertical, to maintain the main lobe of the antenna pointed to the tag. The antenna displacement covered a 360 degree arc, stopping each 1 degree, and asking the tag at each stop. At each stop, the answer signal received from the RFID tag on the bottle was analysed, checking if an actual signal was received and, if so, the received signal strength indicator (RSSI) was recorded. So, we can determine the angles from which the tag could be read, but also the quality of the radio link.

This procedure was applied to the four full bottles, labelled successively with the different tags. Besides that, the readability around similar shaped empty bottles was tested, to be used as a reference for the full bottles.

## 3 RESULTS

The outcomes of each 360 degree sweep around each bottle can be combined into an individual chart, in polar coordinates, representing what we called readability pattern. Such graphs characterize the received signal strength observed from any of the 360 antenna angular locations. These received signal strength values have been normalized to the maximum received signal strength. There could be some observation angles with no received power, which means that it was not possible to obtain a response from the RFID tag on the bottle when the interrogator is pointed at those angles. An example is showed in figure 3, where the readability patterns around bottles are presented, by using the Alien G model RFID tag on each bottle. The larger readability capabilities are obtained when testing empty bottles, number 1 (Burgundy shape) and number 2 (Bordeaux). These are going to be used as reference for full bottles number 1 (the Burgundy one), and numbers 2 to 4 (the Bordeaux ones), respectively. When the tested bottles are full, the arc at which is possible to obtain a response is reduced considerably, as could be observed in the figure 5. This fact will be the most limitative situation if a RFID-based traceability system must be installed to track wine bottles in a store, during delivery, or at the shop. Besides, the shape of the readability pattern appears to be strongly modified when the bottle is full of wine, which is obviously the status we are interested in when tracking and traceability systems are under deployment. These changes result in huge differences in terms of readability,

depending on the angle at which the tag is interrogated. These effects are observed at figure 5 for one model of tag (Alien G), but they are general trends using different tag models, but also gluing the tag to different locations on the bottle surface.



Figure 3: Normalised RSSI, using Alien model G tags, around the four bottles.

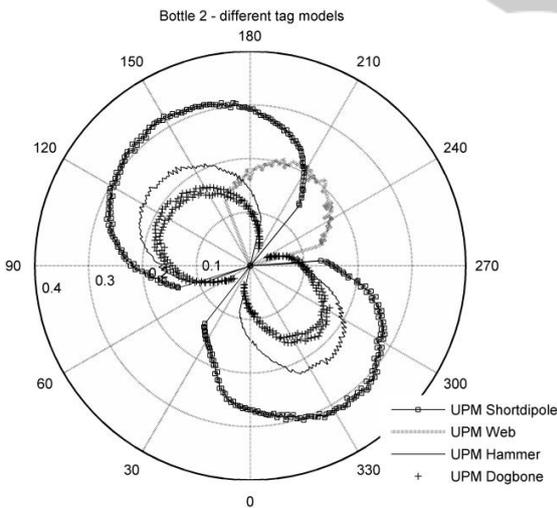


Figure 4: Normalised RSSI, using UPM tags, around the bottle number 2.

Figure 4 shows the readability patterns around a Bordeaux – type bottle (the labelled as number 2), by using different RFID tag models. At the graphs, the dependence on the RFID tag design appears to be very strong, both in terms of shape and of received signal strength as could be tested by observing the scale of magnitudes. The power transmitted by the tags is important to be interrogated, of course, but the angular arc at which

a response is received is probably the crucial factor: weak responses could be amplified or received with more sensitive equipment, but silences have no technical solutions. This means that the arc of observation may be the key parameter to determine the best tag model for the specific application. Table 2a-b contains the values of the readability arcs, i.e. the angular arcs at which the RFID interrogator receives a response from the tag on the bottle.

Table 2: Readability arcs in degree; with tags: (a) UPM; (b) Alien.

bottles	UPM RFID tags				
	dogbone	short d.	hammer	web, H	web, V
1	304	120	125	199	99
2	295	280	231	96	96
3	309	268	251	199	112
4	292	265	202	105	122

(a)

bottles	RFID Alien tags			
	squiggle	2x2	G	short
1	260	217	301	312
2	262	185	360	278
3	270	211	327	299
4	272	164	329	307

(b)

The first immediate observation on the results is related to the shape of the readability pattern: whereas the interrogation around an empty bottle always obtains an answer from the RFID tag, this changes when the bottle is full of wine. The presence of wine, and probably any other liquid, inside the bottle induces a strong modification in the capability of exciting the circuits at the RFID tag and, so, in the possibility of getting a response. It is well known that liquids in general are not friendly materials for radio electric wave propagation (Zhang et al., 2009), and the results confirm this asseveration, as could be detected in figures 3 and, and in table 2. The measurements around empty bottles indicate that it is possible to read the tag independently of the interrogation angle. However, when testing full bottles, the readable arc is reduced, sometimes to less than 100 degree. Besides, the RSSI values around empty bottles are always larger than at full bottles.

The effect of gluing the tag on the bottle at different heights is also interesting. The experiment, this time, consisted in repeating the circular movement of the antenna interrogating the tag when this was glued on the bottle at different heights from the bottom. The distance from the tag to the bottle

bottom was measured from the centre of the tag, which allows the comparison among different tag models. Observing the results, it appears that increasing the distance to the bottle bottom implies a reduction in the received signal strength from the tag, whereas the pattern maintains its shape. In nearly all the cases the largest reading arc seems to be obtained in the tag positions nearest to the bottom of the bottle (between 7 and 8.5cm).

Table 3: Best tag position regarding reading arc; with tags: (a) Alien G; (b) Alien Squiggle.

bottle	wine	ALIEN G tag		
		Best position of tag's centre (cm)	Arc width (°)	Maximum RSSI (a.u.)
1	white	8.5	314	10087
2	red	7 or 7.5	360	10497
3	white	8.5	345	9337.3
4	red	7.5	333	9849.8

(a)

bottle	wine	ALIEN Squiggle tag		
		Best position of tag's centre (cm)	Arc width (°)	Maximum RSSI (a.u.)
1	white	7	160	1262.5
2	red	8.5	247	1458.4
3	white	11.5	196	1298.5
4	red	7	246	1647.7

(b)

The results appear to show that the location of the tags has low influence on the shape of the readability pattern but it has large weight on the power emitted by the RFID tag, and even in the angles at which the tag is possible to be read. In terms of reading arc the positions nearest to the bottom of the bottle seem to be more convenient (see table 3). At these tables, the maximum RSSI is measured in arbitrary units, which represents the value given by the handheld reader after interrogating the tag. The success in selecting the satisfactory location will lead to better performance in the interrogation capacity.

The previously commented results will be useful to select the most adequate tag model and bottle location when implementing a RFID-based traceability and tracking system for wine bottles as proposed in RFID-F2F project. The use of such FF tags would allow the control of bottle storage, and combining with temperature sensors it would also improve the conservation conditions tracking along the distribution stage.

## 4 CONCLUSIONS

This paper presents a system to trace and track wine bottles by means of radiofrequency techniques, using the so-called RFID technology. Previously to the implementation of such a system, some experiments have been performed around different wine bottles, by means of a complete collection of commercial RFID tags. Up to four different bottles and up to eight RFID tag models have been involved in a large electromagnetic measurement campaign.

The results presented along the paper indicates that the performance of the tracking system, in terms of its capacity of effectively detect the RFID tags on the bottles, depends on several factors, as the own design of the tag, the location of the tag on the bottle side, and the bottle shape.

Depending on the design of the tag, there are tags that are able to be read from many angles of observation, whereas there are others with small visibility arcs. In any case, when the bottle is empty, they could be read from all around, which means that the presence of the wine affects in a different way as a function of the design of the tag. Thus, a good selection of tag design would be a key factor to the success of the system.

Depending on the location of the tag on the bottle side, the received signal strength at the RFID interrogator varies and also the arc at which the reading is possible, although the shape of the readability pattern appears to be approximately the same. This means that a precise selection of the location would lead to better readability performance of the system.

Although the measurements have been done in controlled environments, the results are promising. They seem to show that the proposed system could be successfully implemented in actual wineries and stores, being used to trace and track the bottles, as well as in markets where final consumers could access the data related to the product, increasing their confidence on its process and quality.

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