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Experimental evaluation of the passive RFID Technology in Pulse Wave Mode

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Abstract

This paper presents an experimental evaluation of RFID when the traditional sine waveform is replaced by pulse waveforms. This orientation is justified by recent works that show an interest in terms of improving the efficiency of energy recovery on the one hand and a better robustness to complex propagation environments on the other hand.

1. Introduction

Passive UHF (Ultra High Frequency) RFID (Radio Frequency IDentification) is now a widely deployed technology in many fields. In addition to the identification function, the information capture function has been added in recent years, further expanding the field of its applications [1]. Its applications cover, for example, the fields of people, animal and goods tracking, access control, condition monitoring of perishable goods and the cold chain, or massively distributed sensor networks.

Passive RFID as a wireless communication technique has as main originalities to rely on the principles of retro-modulation and remote powering: the tag is passive and does not contain any source of energy not more than a radio transmitter; exploiting the sinusoidal radiofrequency wave emitted by a reader in its vicinity, by recovering energy the tag is self-powered, and in order to retro-broadcast a wave carrying two states of binary information that can be detected by the reader, it switches its charge on two different states.

Recent studies have shown that the use of specific waveforms other than sinusoidal, in particular pulse-like, allowed on the one hand, to optimize the efficiency of the electronic circuits performing the energy recovery (i.e. the RF-dc conversion) and on the other hand, to offer more robustness to the radio link in the presence of multiple paths [2-4].

This study aims at evaluating in practice the performance of a passive RFID communication when the sinusoidal waveform emitted by the reader is replaced by a specific waveform. In this context, it is only a matter of "allowing" to modify this waveform. In this sense, the RFID communication will be established by respecting the ISO 18000-6c standard and by using commercial UHF RFID tags (without any modification).

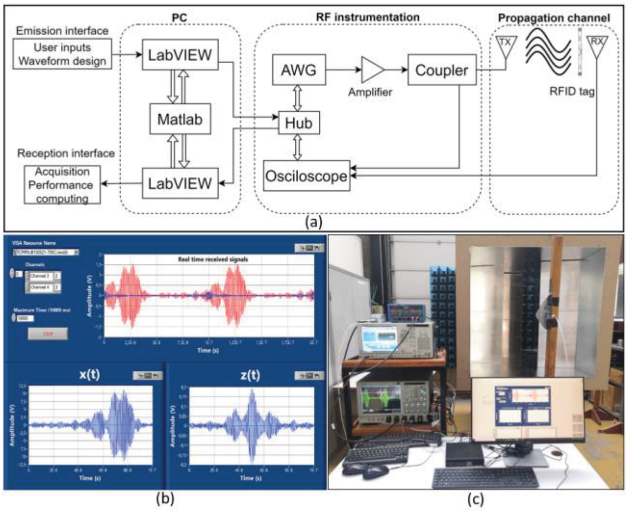

Figure 1. Presentation of the experimental platform used: a) Functional synoptic of the bench; b) Example of interface; c) Illustration photo.

2. Experimental Platform and Waveforms

If there are commercial test and measurement systems specifically for RFID including different standards and adapted for UHF RFID tags, but also HF (High Frequency) RFID tags or NFC (Near Field Communication) tags, they do not allow to modify the sinusoidal waveform transmitted by the reader.

Within the framework of this work, we have developed an experimental platform, called "RFID Waveformer" which allows to emit arbitrary waveforms following the regulatory communication protocol of UHF RFID (Figure 1) [5].

This experimental bench consists of a reader emulated by a LabVIEW interface controlling radiofrequency laboratory instruments, which perform real time tag response detection. Its interconnection with MATLAB routines enables the design and the evaluation of arbitrarily shaped RFID waveforms. As illustrated, the emulation of the reader is realized concretely with the help of an arbitrary wave generator (AWG), which is therefore integrally controlled, and uses the transmitting antenna (TX) to emit the radiofrequency (RF) signal. The receiving antenna (TX) allows to capture the signal retro-modulated by the tag with the help of a digital oscilloscope.

Figure 2 shows the signal waveforms for the three configurations considered: emission of a "1" and emission of a "0". The curve above corresponds to the traditional case with a sinusoidal waveform, called continuous wave (CW), in connection with the signal envelope. The signal presented in the center, noted PW (Pulse Wave) is an impulse signal that is constructed from a cardinal sine function weighted by a Hanning window. It is possible to vary the period (T_0) and also the frequency band occupied (by simply modifying the characteristics of the cardinal sine function). The third signal, noted TR (time reversal), is also based on a pulse signal whose shape is not predefined but adapted to the communication channel on the principle of the TR technique. As for the PW signal, it is possible to modify its period (T_0).

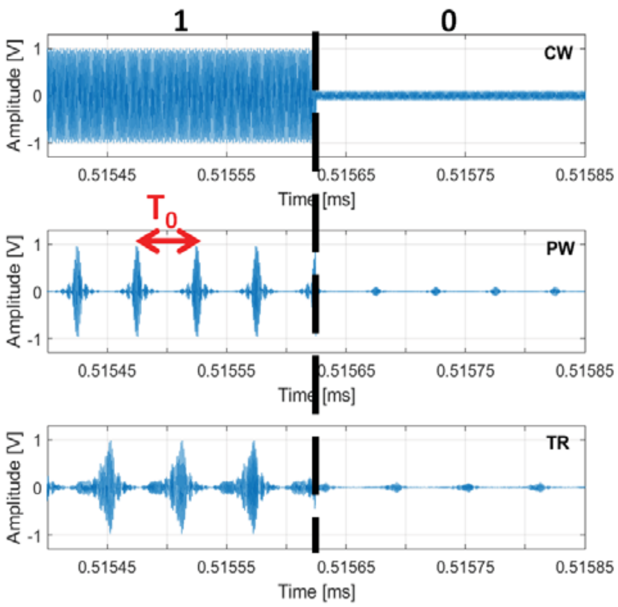

Figure 2. Illustration of the waveforms of the radio frequency signals emitted by the reader: continuous wave (CW) case; predefined pulse wave (PW) case; pulse wave case adapted to the communication channel, called TR (Time Reversal).

Figure 3 presents the ideal case of the frequency spectrum of these three waveforms to illustrate the conceptual approach. In CW mode, all energy and information are carried by a single frequency. For the PW and TR modes, the energy is distributed among several carrier frequencies, providing robustness against channel effects: in the PW case the energy is equally distributed, in the TR case it depends on the channel characteristics. It is interesting to note that all these carrier frequencies carry the information involved in the uplink and downlink communications.

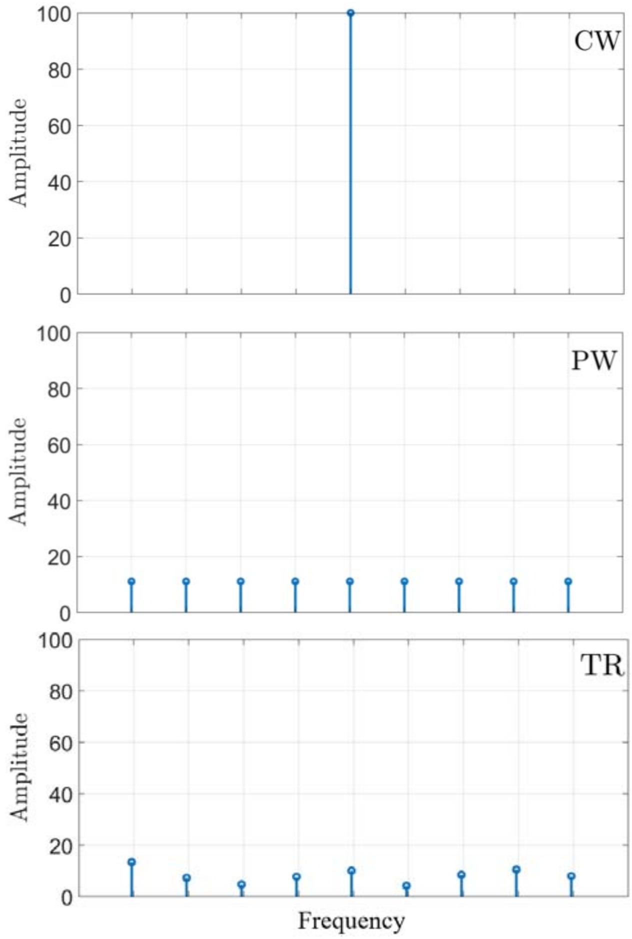

Figure 3. Illustration of the frequencies spectrum for CW, PW and TR cases emphasizing the difference of strategy in terms of spectral allocation: example with a distribution on 10 frequencies at constant total energy.

3. Results and Discussion

In order to compare the three types of signals considered, the criterion used here is the difference between the two voltage levels of the backscattering signal which is noted ΔV. This indicator is relevant in the sense that the greater the difference between the two levels, the easier the detection will be, and in the presence of noise the more reliable it will be.

The references of the tested commercial RFID UHF tags are the following: SML GB4U8; AD Smartrac Accessory; AD-222. The propagation channel is an arbitrary multipath channel. The frequency band explored extends from 700 MHz to 1.1 GHz, the interval on which the tags could be activated and their responses observed. More precisely, the AD-222 tag responds on this entire interval; the SML GB4U8 tag on the 840 MHz to 1.1 GHz interval; and the AD Smartrac Accessory tag on 890 MHz to 1 GHz. The emitted power corresponds to the minimal activation power.

Tag	ΔV (mV) CW		ΔV_{sum} (mV) PW			ΔV_{sum} (mV) TR		
	Min	Max	100 MHz	200 MHz	300 MHz	100 MHz	200 MHz	300 MHz
SML GB4U8	0,062	1,6	1,05	1,21	0,87	0,87	1,23	1,125
AD Smartrac Accessory	0,2	0,8	0,62	0,97	0,62	0,75	0,97	0,94
AD-222	0,08	1,87	2,58	2,92	1,9	2,33	3,44	2,95

Table 1. Performance comparison in terms of backscattered signal voltage level difference for three different commercial tags.

Table 1 summarizes the obtained results. For the CW case, the minimum and maximum values of ΔV are indicated, each corresponding to a particular frequency value of the sine wave. It is important to understand that the observed value depends on the tag itself but also on the transfer function of the channel which is not a constant here, because the channel is multipath and therefore frequency selective. For the two other cases considered, as the transmitted signal is a pulse wave, the backscattering signal is also a pulse wave and the backscattered information is carried by all carrier frequencies. The determination of ΔV is then carried out for each frequency before being summed up to determine the final ΔV_{sum} values. Furthermore, three frequency bands are considered and compared: 100 MHz, 200 MHz, 300 MHz.

Among the results that can be drawn from these experiments, we highlight here some observations that seem essential. It should be remembered that the values measured depend on the characteristics of the channel, but the trends observed are very general. We can notably observe that the increase of the considered frequency band allows to improve the detection when we go from 100 MHz to 200 MHz but not from 200 MHz to 300 MHz. This tendency shows the effect of the bandwidth of the tag which is limited. It is therefore interesting to use several frequencies provided that these frequencies are obviously seen and re-emitted by the tag. On the other hand, it is important to note that the use of pulse signals allows the effects of channel selectivity to be averaged out. From this point of view, there is a real robustness in terms of performance compared to the CW case where the frequency used can be very attenuated.

Note that it is not observed that the channel adaptation of the waveform is decisive to improve the performance: the PW and RT cases seem indeed quite close. The improvement of the RT case is significantly reflected not in terms of ΔV_{sum} but in terms of energy gain.

To illustrate this, Figure 4 shows for the AD-222 tag the impact of the period T_0 of the pulse train on the minimum activation power. The blue curve (CW) is constant and serves as a reference. The tag is activated for a power of 40 dBm in this particular channel; note that this value is greater than the minimum power authorized by the standard. However, it is decreased by using the pulse waveforms, and this is to the advantage of the TR case which considers the characteristics of the channel.

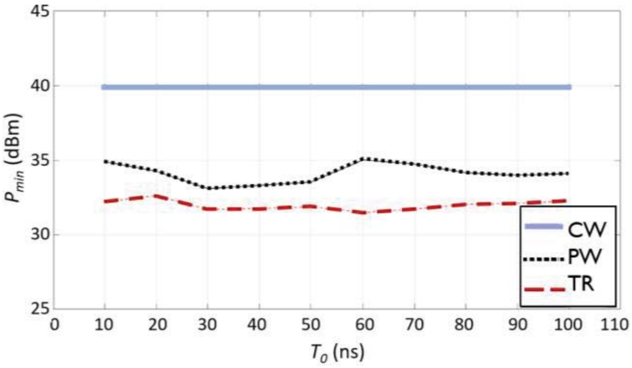

Figure 4. Minimal activation power as a function of the period of the pulse train.

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