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RFID Indoor Locating Model for Medicines Tracking

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***Abstract** Anti-cancer fighting progresses on all fronts. Researchers currently develop medicines able to starve tumors to fight against this terrible plague responsible for 150,000 deaths per year but they still expensive. Indeed, the development of a system of distribution rationalization and medicines use inside health care institutions and centers (hospitals, therapy centers…) seems to be obligatory to save patients' lives. Therefore, we propose an indoor locating and tracking system based on RFID and an UHF RFID locating system environment. Its concerns therapeutic medicines management within pharmacies of health care institutions favoring two approaches: positioning in oncology centers and access of medicines by patients.*

***Keywords**: RFID, UHF, Model, Positioning, Locating techniques, Traceability.*

I. INTRODUCTION

Traceability is a procedure to automatically follow a product during its manufacturing process, its distribution until its consumption and it must be able to localize and identify constantly. It became an industrial challenge, a communication axis to reassure consumers. Objectives of traceability and identification logistics are simple:

- Effectiveness improvement of logistic management control;
- Stocks tracking;
- Tracking until goods reception;
- Customers or partners satisfaction;
- Deadlines and costs reduction;
- Warranty quality: possibility of withdrawing a non-conform product during manufacturing or distribution.

There still, in pharmaceutical sector traceability is a public health question. Regulations are thus very rigorous; each drug must be codified with clear information, so it will be able to recall the tracking history. According to each industrial problem a system ensuring identification and logistic traceability exists. Base soften the same, each product must be provided with an ID. a reader must be able to read and process contained information in the login.

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Two methods are usually used by companies: Code-bars traceability system and radio identification traceability system.

Code-bars system showed its deficiency. Stocks tracking by code-bare identification is very largely widespread. It is practically used in all industrial sectors.

Multiple information can be contained and treated within cade-bars; however, information storage capacity remains limited. This system offers many advantages like simplicity, speed, reading reliability and its low cost. Nevertheless, its lifetime is short as it deteriorates quickly and industrial labelling implies various technologies, software and readers.

Radio identification system is found in many industry branches. It makes possible to store information and remotely recovered these data using the tag that is attached to products, or even introduced inside.

In order to obtain a precise drug tracking history within health care institutions, indoor locating methods is needed. Several technologies of proximity allow reaching metric precision. In addition, the emergence of new wireless networking [1] is a solution to locate inside buildings. Other technologies like those with active/passive tags or those of vision (video...) are also used to locate. However, Different existing locating techniques are:

- Ultrasound;
- Infra-red;
- Video;
- Magnetic field measurement;
- Measurement of phase of electromagnetic components;
- Radio wave (Wi Fi, Bluetooth, RFID, ULB).

In this paper, we present an RFID over wireless network locating and tracking technique of medicines inside a health care institution or an oncology center.

II. LOCALIZATION BASI5C CONCEPTS

It is difficult to identify in an exhaustive way all the parameters that characterize localization systems. Indeed, knowing well the environment can make possible to create services adapted to the study case. Basic concepts of localization [2] are:

A. Context and situation

Context is every information which can be used to characterize the situation of an entity. An entity is a person, a place, or an object which concerns a system user and an application intersection, taking in consideration the user and the application » is a concise definition published by Dey and Abowd.

From this definition, four types of context focused on existing relation between a mobile system and its related elements.:

- Infrastructure;
- System;
- Field;
- Physical content.

Whereas the context is seen like a set of variables making it possible to describe the state of a user according to its environment (hospital), the situation as for it, describes another variable with more precise significance.

B. Localization based system

It is a software application for a compatible portable device Internet Protocol (IP) which requires the user position knowledge. Services of localization can be found on a request to provide the end-user useful information or they can be in push mode to offer coupons, or other marketing information for users who are in a specific geographical zone. These systems offer services once we know user position with a certain exactitude.

C. Various categories of localization

Since localization systems use its users' positions, it is thus important to identify the various existing categories.

- Descriptive localization

It is always related to natural geographical objects like territories, mountains, lakes…

- Localization based on the network

It refers to a communication network topology (in mobile telephone networks, one localization network is connected to a base station to which a mobile terminal is attached to obtain the location).

- Space localization

It targets a single point in a Euclidean space. Another term, more intuitive for the space localization is thus the position. It is generally by means of contact into two or three dimensions, which are given by components of a vector, each one of them allowing to fix the position in one dimension. Our study is related to this last category of localization.

D. Reference

Reference is the point used to give an object or a parson position. It can be a receiver or a transmitter. All depends of the application type. Thus, according to the user, we can distinguish two positions types: absolute and relative positioning.

E. Transmission support

The basic element of any system of localization is the type of used signal to locate. Several technologies are used by localization systems which are based on the infra-red one, optical signal, ultrasonic signal, radio-frequential signal (Radio Frequency (RF)).

F. Elements of the localization process

Positioning is a process who allows a target to obtain its position, which differ from/to each other by a certain number of parameters such as quality, the cost of realization, costs of deployment and exploitation.

III. UHF RFID LOCATING MODEL

We present a model of medicines locating system which define our study environment. We chose RFID locating technique because it is wireless, uses unique identifier, allows tracking and identification of a big number of objects with flexibly. Among different types of RFID tags, we used passive ones as they don't need any power sources and the system will be low cost. For this modeling, we are interested by Ultra High Frequency mode (860-960 MHz) [3] to achieve higher data rates, higher communication ranges and smaller antenna size. For this, we developed it using MATLAB-Simulink based on how real UHF RFID locating system performs taking into consideration the different interactions between tags and readers.

A. RFID model

We designed an RFID model inspired from [2] that is based on the implementation of the forward link and return link of the system between tags and readers, and the data processors using MATLAB-Simulink.

At first, we define blocks like the reader as well as the tag and the environment conditions of communication.

1) Transmission model

- Repeating sequence code (ID)
- Continuous carrier signal (A=1V, Freq=865Mhz)
- Additional Gaussian noise (with SNR of SSB=DSB)

2) Channel model

Wireless media between reader and tag (AGWN channel).

3) Passive tag model

- Comparison blocks for code matching identification.
- Continuous carrier modulated with tag ID for tag activation.

4) Receiver model

Circuit with large dynamic range to receive direct signal from the transmitter and the reflection one.

5) Locating model

Calculation blocks for positioning identification and synchronisation with the reader.

We intend to create a model enabling to choose amount of tags, dimension of the locating zone, parameters of communication and identifiers [4]. It consists of some modules allowing a successful RFID identifier and locating system (Fig. 1.).

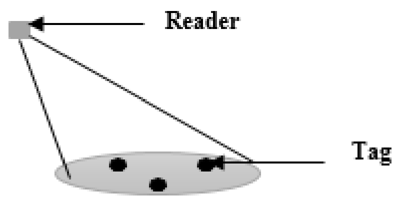


Fig.1. Scheme of the RFID locating model

We designed and simulated our RFID model withpassive tags employing MATLAB-Simulink with incorporation of all practical environmental aspects. For the rest of our simulation, we will consider a wave reflection time Fig. 1.

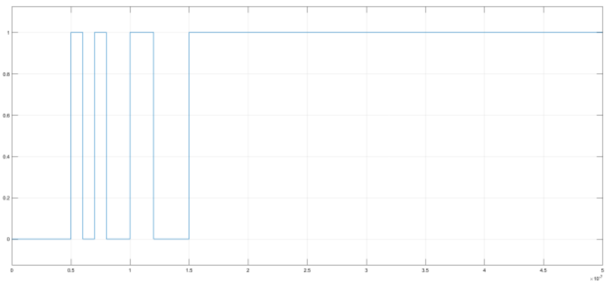
In order to validate the developed model, we simulate using the following set parameters:

- Tag ID: 0000010100110;
- Freq=865MHz;
- Emission power 100mW ϵ [100mW,500mW] ;

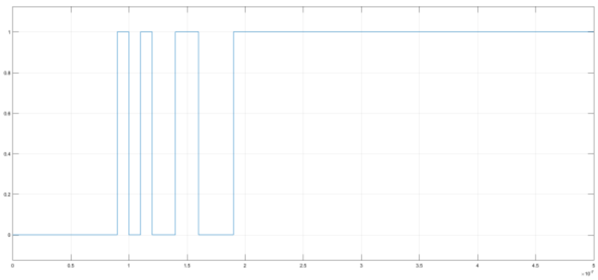
- according to ETSI EN302 208 parts 1&2 v1.2.1 and ETSI EN300 220 part 1&2 v2.1.2 [5] ;
- Electric field E (V/m) : 40.4 (Table.1) ;
- Attenuation factor per meter: 0.11

a) Case 1: the tag is next to reader

When UHF RFID tag is near to the reader, we notice that RX signal which is already processed in the reader block is the same signal waveform in TX with a wave reflection time delay.



(a)

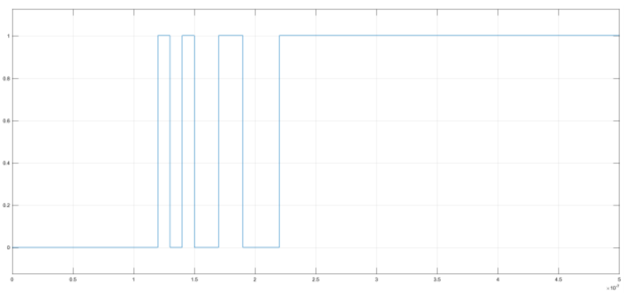


(b)

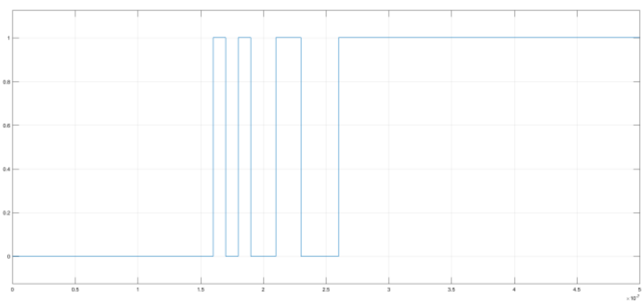
Fig. 2. (a) Emitted (TX), (b) received (RX) signals in case 1

b) case 2: Tag is far from reader

In this case, the tag is still in the reading zone and receives same sent waveform with wave reflection time and a delay while the tag changes its position and it is going away from UHF Reader (opposite direction).



(a)

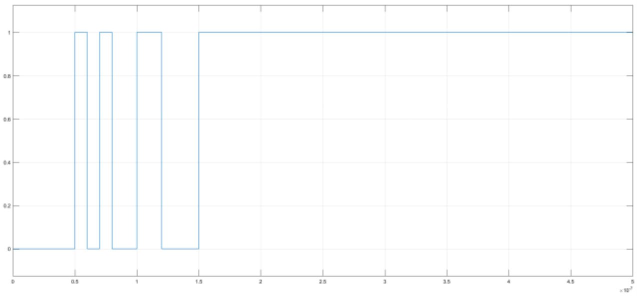


(b)

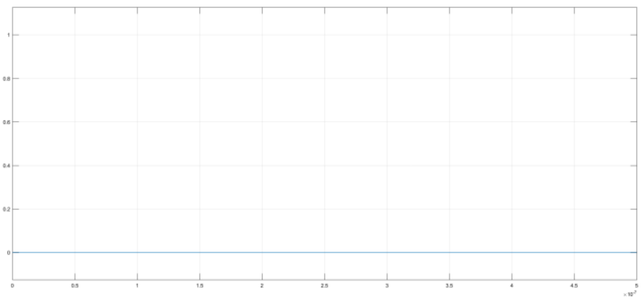
Fig. 3. (a) Emitted (TX), (b) received (RX) signals in case 2

c) case 3: RFID Tag isn't in the reading zone

It is apparent that there is no received signal and it is related to the use of a delay upper to the maximum delay fixed for to detect a signal in our simulation.



(a)



(b)

Fig. 4. (a) Emitted (TX), (b) received (RX) signals in case 3

B. Locating Technique

Radio wave energy, because of interactions with the environment, decreases when it moves at a certain distance. Consequently, they can be used to recover space information. The metric which uses this principle named received Signal Strength (RSS). This technique consists in estimating losses by attenuation of

the signal during the propagation. From Friis equation (1), a propagating wave in free space losses of energy according to the distance separating the transmitting source and its receiver is given by (2). Where we used the equation c=f*λ between the wavelength λ, the frequency, the speed of propagation of light c. PL(f,d) represents the ration in dB between the emitted and the transmitted power. As Gt and Gr represent respectively, emission and reception antenna gain. Channel variations are mainly due to propagation power losses and masking mechanisms.

$$\frac{Pr}{Pt} = Gt * Gr * \frac{\lambda}{4\pi d} \quad (1)$$

$$PL(f,d) = 20 * log\left(\frac{4\pi f d}{c}\right) - Gt(f) - Gr(f) \quad (dB) \quad (2)$$

Locating and identification process use then the emitted power (with an electric signal in the UHF band 860-960 MHz) because of its advantages such as a simple algorithm, various attenuation mathematical models and signals aren't multi-path in our study case. Our designed model is valid according to the CEPI (European Union) as [5] we used real values for our simulation (Table1).

Table1. Limit Reference level values for 860-900MHz

Frequency (MHz)	Electric Field E (V/m)	Magnetic Field H(A/m)	Magnetic induction (µT)	Power density of a plane wave S (W/m²)
865	40.4	0.108	0.136	4.325
900	41	0.11	0.14	4.5

Furthermore, Emitted power decreases with distance due to environment interaction, and we can reach the maximum power level when the tag is nearest to the reader (Fig. 5).

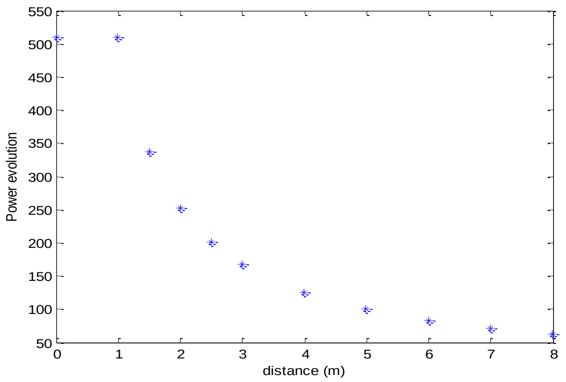


Fig. 5. Emitted puissance evolution per meter

C. Relative position calculation

We apply the triangulation method which use at least two known angles of arrival (AOA) θ1 and θ2 indicated in Fig. 3in addition to the distance [S1S2] separating two readers.

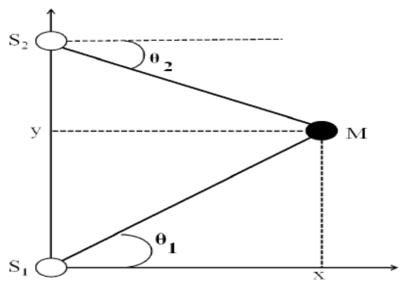


Fig. 6. Scheme of AOA

M(x,y) is a mobile with an unknown position, and the source of the received signal by S1(x1,y1) et S2(x2,y2) as the emitted signal is reflected by the tag. AOA are measured respectively, between (MS1) et (MS2) axes and their perpendiculars with the direction of (S1S2) in S1 and S2. They are estimated either using directive antennas or a network of directing antennas by supposing that the first signals always arrive according to a direct way. To determine M position, let us define a reference mark S1 like origin and (S1S2) of y axis [6].

Then, using (3) and (4) we can easily determine the characteristics of triangle S1MS2 and get the position.

$$x = \frac{S1S2 * cos\theta2}{\sin(\theta1+\theta2)} \quad (3)$$

$$y = \frac{S1S2 * cos\theta1}{\sin(\theta1+\theta2)} \quad (4)$$

M (x, y) position is then given by:

$$x = \frac{S1S2}{tan\theta1 + tan\theta2} \quad (5)$$

$$y = \frac{S1S2 * tan\theta1}{tan\theta1 + tan\theta2} \quad (6)$$

Simulation model can add a random delay in every simulation cycle to simulate distance variation. Then, we determine the locations using (5) and (6):

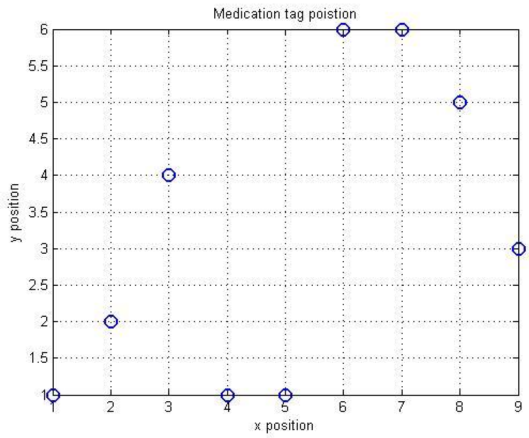


Fig. 7. calculated position x and y

Location blocks calculate positions in 2-D. When the tag is inside reading zone, relative position blocks calculate its position (S1M, S2M). Otherwise, each position block calculates the position as if the reader coordinates (0, 0).

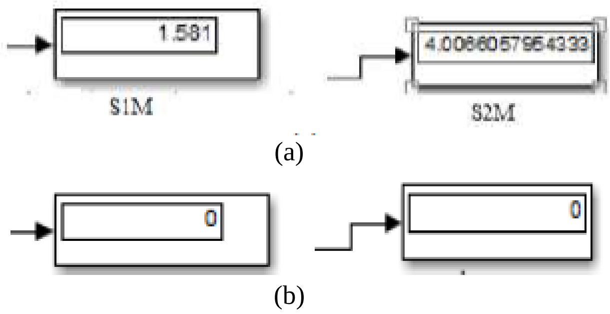


Fig.8. (a) S1M and S2M when the tag is inside the reading zone, (b) S1M and S2M when the tag is out of the reading zone

D. RFID locating system model performances

To test our locating model performances, we created another an indoor positioning model with a known positions S1M and t' which is a delay. We used the wall and floor factor model, which is a pico-cell determinist model adapted to our simulation frequency and consider the path loss. (7) is the attenuation equation for the wall and floor factor model.

$$L = L1 + 20 * log(r) + nf * af + nw * aw \quad (7)$$

af is the attenuation factor per stage, aw the attenuation factor per wall, L1 is the path loss reference at 1m and r is the traversed meters numbers. In our case, we supposed that attenuation per stage and wall does not exist, so aw and af equal 0 and (7) will be

$$L = L1 + 20 * log(r) \quad (8)$$

We calculate S1M (r) position using (8) with L1=0.11 according to ETSI EN302 208 parts 1&2 v1.2.1 and ETSI EN300 220 parts 1 and 2 v2.1.2, which will be the first input for our previous testing model. Moreover, t' which an input for our RFID locating model is obtain with (9) (V=c, and t=t0 + t').

$$V = \frac{d}{t} \quad (9)$$

In addition, using the transmitted and received powers and (1) We can have the attenuation factor values which will be a second input for our previous model.

We obtain then an indoor positioning model based on the wall and floor factor (Fig. 8). "consigne" is the RFID tag signal to ensure the locating model and the testing one synchronization in the transmission and the receiving phases. S1M according to t' (delay) results for floor and wall factor testing and RFID locating model are identical which confirms the precision of our model (Fig. 9).

Fig. 9. Floor and wall factor testing model for RFID locating model.

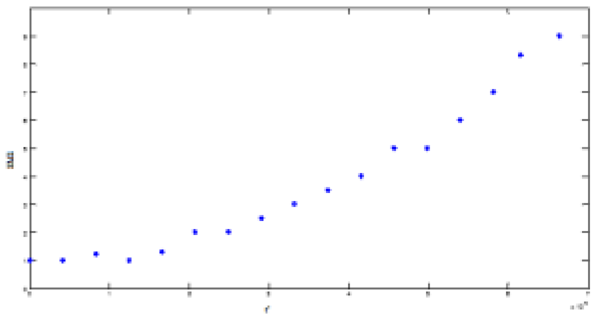


Fig. 10. S1M according to t' for both floor and wall factor testing and RFID locating model.

1) Absolute tag position

For this we need at least two readers communicating over a wireless local network [7]. The architecture we used in our study (Fig. 10.) is mini-local network with three readers which can read one tag per transmission cycle.

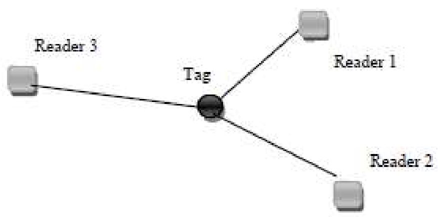


Fig. 11. UHF RFID system architecture for absolute position calculation

This method is based on the intersection of each reader-tag line (Fig. 11), as for 2-D dimension it is a sufficient condition to get position. Let us place the reader respectively in R1(0 ;0), R2(5 ;6), R3(8;2) and calculate our tag position at previous position 3 (knowing that the tag isn't mobile for the moment).

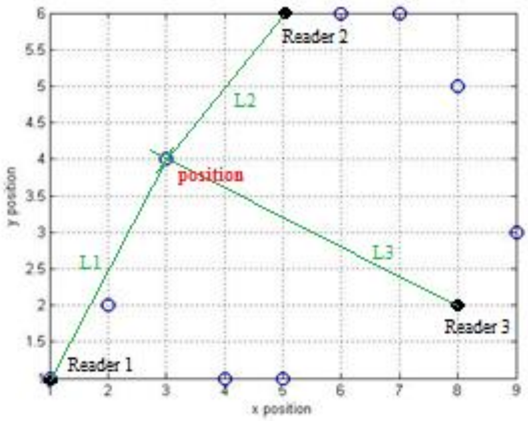


Fig. 12. absolute position calculation using lines intersection method

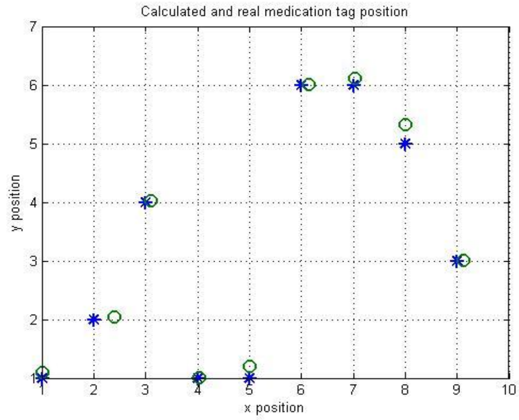


Fig. 13. absolute position calculation using lines intersection method

We exploit relative positions to have the relative ones using lines intersections and obtained similar results with a tolerated error (Fig. 13).

All the locating system was designed and developed in case of noise variance (Wall attenuation, interferences with other signals.) equal zero. We choose a random tag trajectory and modify noise variance in the transmission channel to study our model locating performance.

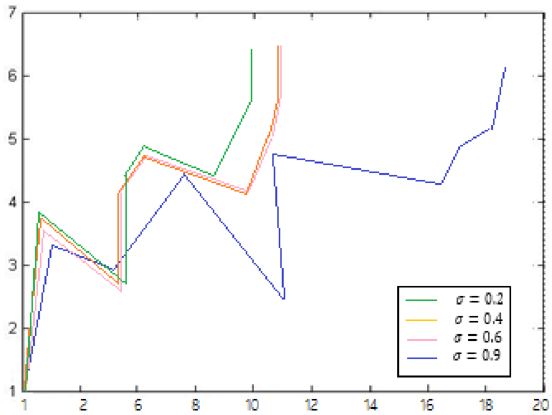


Fig. 13. S1M and S2M position with different noise variance values

When noise variance is less than 0.45, the trajectory and the tag positions are similar with an error less than 1 meter which is tolerable in our positioning case. Then, when noise variance is less the 0.55 positions and trajectories are the same but a large error. Finally, once we reach higher noise variance error, the positions are completely wrong.

2) Multi-tags positioning case

We try to locate multiple tags at the same time. We keep the same architecture of our mini-local network (Fig. 10) and add tags with different ID within the readers reading range [8].

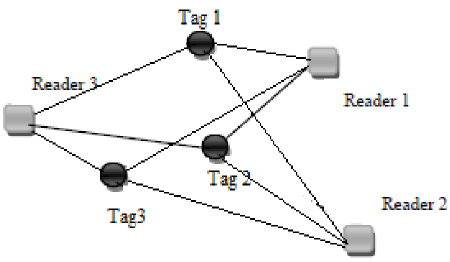


Fig. 15. Network architecture in multi-tags positioning case

To identify tags signals whether in the presence or the absence of noises, we used the LMS filter. It permits to get the wanted signal (tags signal) from the receiving one (Fig. 16).

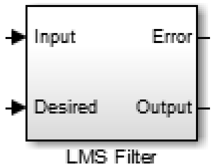
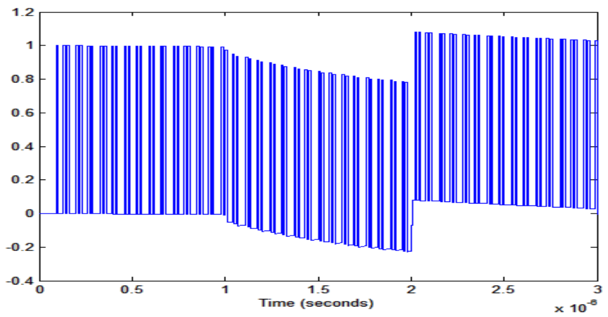
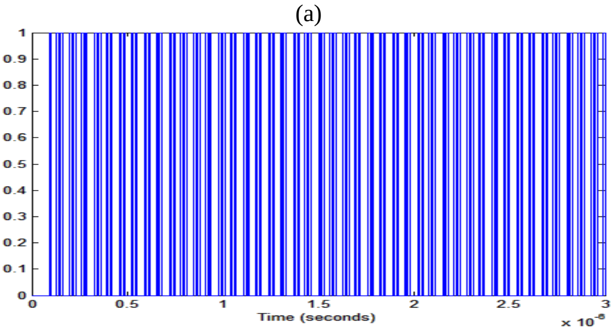


Fig. 16. LMS filter to identify tag signals



(a)



e(b)

Fig. 17. (a) Noised RFID tag signal (b) Reconstructed RFID tag signal (repetitive sequence) during the simulation time

We placed reader respectively at R1(1;1), R2(5 ;6), R3(8 ;2) and calculate the absolute position (Fig. 17).

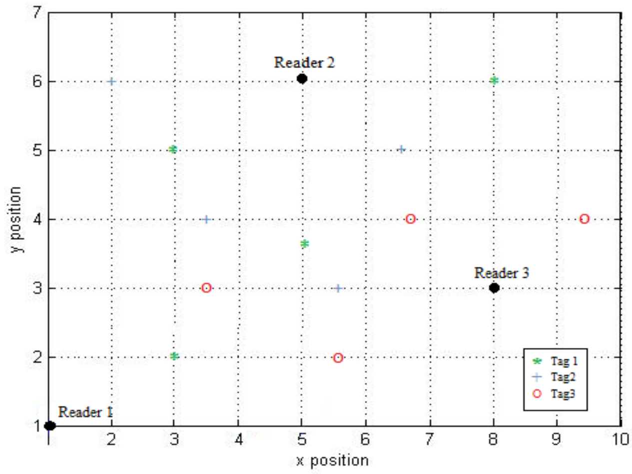


Fig. 18. Multi-tags indoor positioning map

IV. CONCLUSION

In the medical field (Hospitals, therapeutic centers…), the installation of an effective pharmaceutical traceability aims to ensure an efficient medicines tracking constantly, ensure the availability of the medicines in various health cares and oncology centers, protect patients and preserve public health, make sure of the compatibility of the medicines with the patient, and build an information system with quality assurances. Indeed, this paper presents an indoor RFID locating system model and environment that permits an optimized speed and effectiveness medicines traceability. Thus, it does not require a contact with an important storage capacity and has a ten-years lifetime.

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