

The RFID Radio Channel Performance in the Vehicular Control

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ABSTRACT. Most terrestrial wireless communication systems operate in environments that present a multitude of RF propagation problems. The Radio Frequency Identification (RFID) System, a wireless communication system, applied to vehicular control, is a typical point to point communication system, which one, the radio link formed between the reader, working at the same time as base station and as an end user site, and the tag, the intermediate site, is exposed to electromagnetic disturbances, due reflections off objects in the environment. Meanwhile any misalignment between the antennas at the reader and the tag will result in a polarization mismatch, from which, added to the multipath propagation, the system will see a slight fall of some level of reduction efficiency.

The focus of this article will be a discussion of the path loss in the RFID communication system applied to vehicular control, owed to antennas polarization mismatch and the ground reflections. Experimental and measurements were taken in the field and in the electromagnetic compatibility laboratory in three and four dimensions.

KEY WORDS: RFID Technology, Path Loss, Vehicular Control, Antenna Transfer Function, Polarization.

I. INTRODUCTION

The radio electric and geometry environment characteristics influence the Radio Channel, which one, have been analyzed extensively in different papers, but no one of them has analyzed the RFID technology applied to vehicular technology. This motivates the analysis of the propagation environment for outdoor RFID systems.

The RFID system uses the near and far field electromagnetic coupling concept, for detecting objects. A wireless communication link, is provided between a remote transponder (antenna and integrated circuit), known as the tag, and an interrogator or reader, as showed in the figure 1. The main functions performed by a reader are demodulating the data retrieved from the tag, decoding the received data, energizing in the case of passive and semi-passive tags, and as an antenna radiating above of a lossy surface [1].

The RFID Technology works in the low, high, ultra high and the super high band frequency. The 18006-C standard establishes the requirements of the physical and logical levels, where the reader starts the communication in the RFID system, operating in the 860-960 MHz frequency range [2], [3].

Recently, this technology is applied to the vehicular control in order to have all the motor vehicle information, for example, owner name, license, fines, etc. It is a radio mobile typical application, showed in the figure 2, where the reader is installed in a fixed position, strapped on a fixed post, as the transmitter, and the tag is strapped on the motor vehicle, as a mobile receiver and starting the

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data back transmission to the reader, living side by side with other communication systems, in a complex and violent electromagnetic environment. In this application the RFID reader is based in the monostatic antenna configuration, with a single transmit and receive antenna [4], where a directional coupler is used as an isolator, which one, introduces additional path attenuation loss. Making up the propagation media, we have the free space, the reflections from ground [5], [6], this one, made of homogeneous isotropic material with linear properties, the electric permittivity ϵ_r , and the magnetic permeability μ_r , and the reflections from the various obstacles, some of them statics, and/or some of them, in continuous movement,

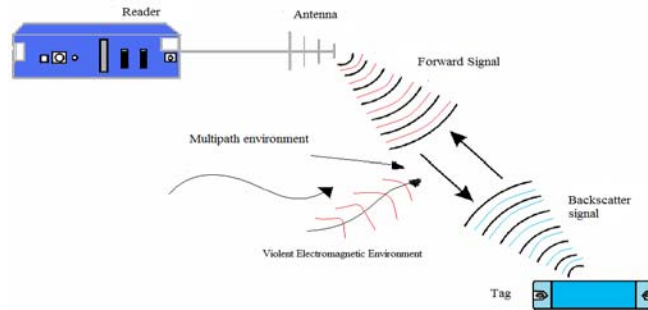


Fig.1. The Radio Frequency Identification Channel

The polarization is an important consideration for RFID reader antennas. For maximizing the tag range, antenna polarization of the tag must be matched to that of the reader antenna. In the RFID applied to the vehicular control, the alignment between the reader antenna and the tag antenna is a difficult situation, due to on motion of the mobile, resulting in a mismatch polarization adding path attenuation loss.

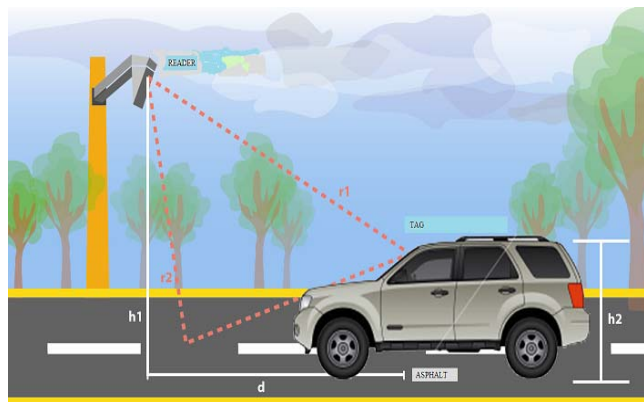


Fig.2. The RFID technology applied to the vehicular control.

The figure shows the components of the radio channel, the direct ray and the ray reflected from the ground.

II. STATEMENT OF THE PROBLEM

A. POLARIZATION MISMATCH

During the tests, a Yagi antenna is used as reader antenna, and it was installed forming an angle with the post. In the other hand, a horizontal dipole is used as tag antenna, which one is installed on the windshield of the motor car.

In order to get a maximum electric field in the antenna of the tag, this one must be matched with the reader antenna, but as long as the mobile is closing to the reader, a mismatch polarization between the antennas is present. Polarization mismatch adds an extra loss. The mutual polarization efficiency is expressed as [7]:

$$P = \frac{1 + |\hat{\rho}_1|^2 |\hat{\rho}_2|^2 + 2|\hat{\rho}_1||\hat{\rho}_2| \cos(\theta_1 - \theta_2)}{(1 + |\hat{\rho}_1|^2)(1 + |\hat{\rho}_2|^2)} \tag{1}$$

where:

θ_1 , reader antenna polarization ratio phase

θ_2 , tag antenna polarization ratio phase

$\hat{\rho}$, complex polarization ratio

The equation 1 represents the correlation between the antennas polarization, and it is a loss due to polarization mismatch. If θ_1 and θ_2 are the phases of the polarization ratios of the antenna, the tag antenna and the incident wave from the Yagi antenna, the maximum and minimum polarization efficiencies occur when $\theta_1 - \theta_2$ equals 0° and 180° respectively. The polarization efficiency becomes:

$$P_{\max/\min} = \frac{(1 \pm |\hat{\rho}_1||\hat{\rho}_2|)^2}{(1 + |\hat{\rho}_1|^2)(1 + |\hat{\rho}_2|^2)} \tag{2}$$

In the other hand the polarization loss factor, PLF, can be expressed as:

$\vec{E}_i = \hat{a}_w E_i$, the incoming wave electric field

$\vec{E}_a = \hat{a}_a E_a$, receiving antenna electric field

Then the polarization loss factor is expressed as:

$$PLF = |\hat{a}_w \cdot \hat{a}_a^*|^2 = |\cos \theta_p|^2 \tag{3}$$

where:

θ_p , angle between the two unit vectors

Figs. 3a and 3b show the geometry formed by the antennas position during the tests.

A 45° angle is made between the Yagi Antenna and the vertical. Meanwhile the mobile is closing to the fixed station, the distance between them is decreasing and the polarization angle is changing too, as expressed in equation (4).

$$\theta_p = \tan^{-1} \left[\frac{h_1 - h_2}{d} \right] \tag{4}$$

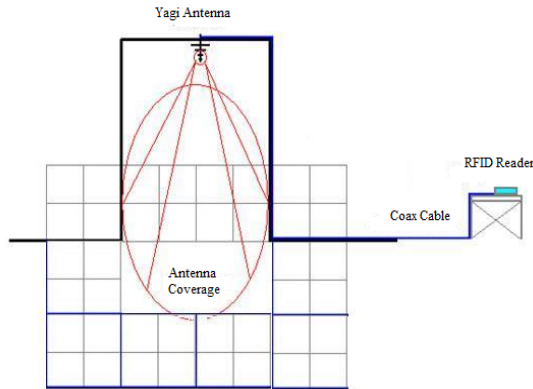


Fig.3a. Polarization Antennas Geometry Frontal View.

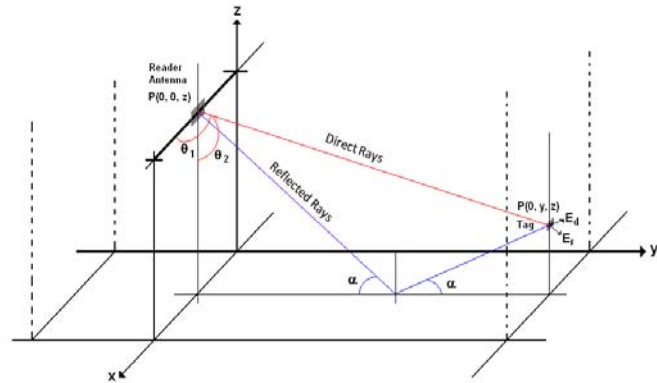


Fig.3b. Polarization Antennas Geometry Lateral View.

B. REFLECTIONS ON THE GROUND

In other hand, the two ray model [8] considers the direct wave and the reflected wave, and the reflection coefficient is based in the electric properties of the reflecting surface and the angle of incidence. So, due to contribution of the polarization loss factor, now the received power can be expressed in this way:

$$P_r = P_t G_t G_r (PLF) \left(\frac{\lambda}{4\pi} \right)^2 \left| \frac{1}{r_1} \exp(-jkr_1) + \sum_{i=1}^N \Gamma(\alpha_i) \frac{1}{r_i} \exp(-jkr_i) \right|^2 \tag{5}$$

where:

P_t , transmission power

G_t , Antenna gain of transmitter

G_r , Antenna gain of receiver

d , distance between the transmitter and receiver

r_1 , distance of the direct ray

r_i , distance of the reflected ray

$\Gamma(\alpha)$, reflection coefficient

being:

$$\begin{aligned} r_1 &= \sqrt{d^2 + (h_1 - h_2)^2} = \sqrt{d^2 + h_1^2 + h_2^2 - 2h_1h_2} \\ r_2 &= \sqrt{d^2 + (h_1 + h_2)^2} = \sqrt{d^2 + h_1^2 + h_2^2 + 2h_1h_2} \end{aligned} \tag{6}$$

and:

$$\sin \alpha = \frac{\sqrt{d^2 + (h_1^2 + h_2^2)}}{(h_1 + h_2)}$$

where:

α , incidence angle

The first part of expression (5) corresponds to the direct ray, now affected by the polarization loss factor, and the second part of the square module, represents the reflected rays.

The reflection coefficient depends of the angle of incidence, signal polarization and the relative permittivity of the reflecting surface. So, due to contribution of the polarization loss factor the reflection coefficient, in each case, is given by [13]:

$$\Gamma(\alpha) = \frac{\varepsilon_r' \cos(90 - \alpha) - \sqrt{\varepsilon_r' - \sin^2(90 - \alpha)}}{\varepsilon_r' \cos(90 - \alpha) + \sqrt{\varepsilon_r' - \sin^2(90 - \alpha)}}$$

Vertical Polarization

$$\Gamma(\alpha) = \frac{\cos(90 - \alpha) - \sqrt{\varepsilon_r' - \sin^2(90 - \alpha)}}{\cos(90 - \alpha) + \sqrt{\varepsilon_r' - \sin^2(90 - \alpha)}} \tag{7}$$

Horizontal Polarization

where:

σ , conductivity of the reflecting surface (asphalt $\sigma = 0.005$)

And the electric permittivity is given by [9]:

$$\varepsilon_r = 15 - j60\sigma\lambda$$

For $\varepsilon_r = 5$, poor ground (dry) relative electric permittivity [10], the receiver power for vertical polarization is shown in figure 4, as the same way for $\varepsilon_r = 15$, wet ground relative electric permittivity [10], the receiver power is shown in figure 5.

The graphic in the figure 4 shows the received power performance.

The constructive contribution of the reflected waves in the received power (the green curve and the sky blue curve), is shown in graphics 4 and 5.

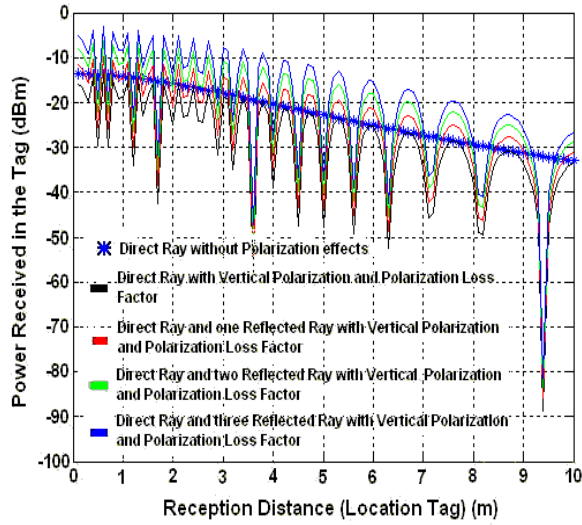


Fig 4. Tag Received Power with $\epsilon_r = 5$ for Vertical Polarization

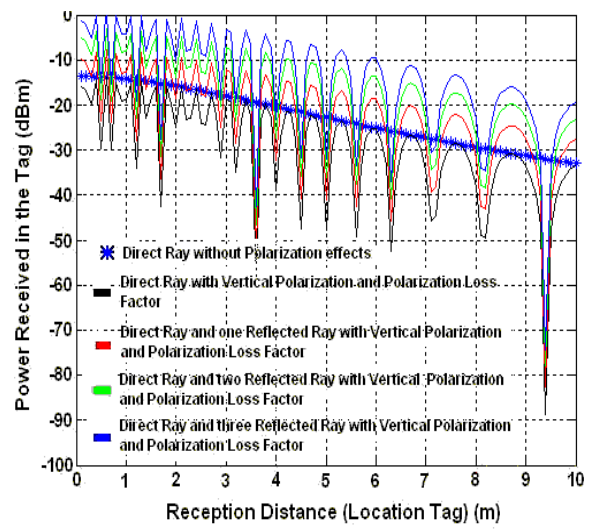


Fig 5. Tag Received Power with $\epsilon_r = 15$ for Vertical Polarization

The facts speak for themselves about the destructive and constructive contributions of the reflections. The figure 6 shows one of the several experiments and measurements made in the field.



Fig.6. Measurements in the road.

III. CONCLUSION

The Multipath propagation, the polarization mismatch antennas, the speed of the mobile, the speed of surrounding objects, the ground reflections and the transmission bandwidth of the signal are the most important physical factors in the radio propagation channel influence. For mobile radio applications, the RFID channel is time-variant because motion between the transmitter and receiver results in propagation path changes.

A propagation model allows us to predict the power, the electric field spatial distribution, and the electric field polarization state, in order to optimize the receiver operation.

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