Analysis of an UHF-RFID System in a Metallic Closed Vehicle

Leire Azpilicueta(1), Jose Javier Astrain(2), Hugo Landaluce(3), Ignacio Angulo(3), Asier Perallos(3), Jesus Villadangos(2), Francisco Falcone(1)
leyre.azpilicueta@unavarra.es, josej.astrain@unavarra.es, hlandaluce@deusto.es, ignacio.angulo@deusto.es, Asier.perallos@deusto.es, jesusv@unavarra.es, francisco.falcone@unavarra.es
(1)Electrical and Electronic Engineering Department, Public University of Navarre, 31006 Pamplona, Spain
(2)Mathematics and Computer Engineering Department, Public University of Navarre, 31006 Pamplona, Spain
(3)Deusto Institute of Technology (DeustoTech), University of Deusto, 48007 Bilbao, Spain

***Abstract*—In this work, a ray-tracing technique to predict the propagation channel parameters in indoor scenarios is presented. An analysis of the physical radio channel propagation inside a van full of buckets is presented. The propagation model is a deterministic technique, based on 3D ray launching. The results show the dependence of the scenario in the performance of the system, revealing that the consideration of the topology of the wireless system prior to deployment leads to an optimal final configuration.**

I. Introduction

The study of the propagation in wireless channel has increased enormously in recent years because of the large amount of competition that exists in mobile communications at the moment. Channel performance directly determines the quality of the communication. Therefore, a very clear understanding of the channel must be known in order to get high-quality and high-capacity transmission of the useful information by using the more limited base stations to give an efficient service. It is important to know the phenomena that affect radio propagation, which the most important is fast fading [1] [9] due to multipath propagation.

Traditionally, empirical methods were used (such as COST-231, Walfish-Bertoni, Okumura Hata, etc.). They give rapid results, but require calibration based on measurements in order to give and adequate fit of the results. On the other hand, deterministic methods are based on numerical methods, as ray launching and ray tracing (based on geometrical optics approximations) or full wave simulation techniques (MoM, FDTD, FITD, etc.) These methods are precise, but are time consuming to inherent computational complexity. As a mid-point, methods based on geometrical optics, for radioplanning calculations with strong diffractive elements, offer a reasonable trade-off between precision and required calculation time [10].

In the automotive sector, simulations by using full wave approaches like ray tracing method have been established to, e.g. optimize antenna positions in the vehicle under consideration of ElectroMagnetic Compatibility (EMC) and electromagnetic field exposure to the user [2] [3]. Therefore, several ray tracing simulations and measurements have been made in metallic indoor scenarios, like the cabin of an aircraft [4] [5] [6] [7] or enclosed spaces [8].

In this work, an analysis of the behavior of a RFID system [11] in a closed metallic van full of buckets of polypropylene material has been done. A 3D ray launching algorithm has been implemented in-house, based on $Matlab^{TM}$ programming environment. Several sources can be placed within an indoor scenario, in which power is converted into a finite number of rays launched within a solid angle. The main characteristics of the overall system are to control medical distribution all over the delivery route and to facilitate the main tasks of the couriers. RFID technology is optimal to guarantee the traceability of medicines delivered and allows van drivers to load and unload cargo from the vehicles with increased security and efficiency, given by automatic interrogation of the status of the loading. Parameters such as frequency of operation, radiation diagram of the antennas, number of reflections, separation angle between rays and cuboids dimension can be fixed. Phenomena such as reflection, refraction and first order diffraction are considered, as well as the material properties for all of the elements within the scenario, given by the dielectric constant and the loss tangent. A view of the van is shown in Figure 1, and Figure 2 represents the ray launching scenario of the van full of buckets.

Figure 1. Carrier loading containers into a van.

II. Results of the simulation scenario

The considered scenario is the case which the van is full of buckets of material polypropylene, stacked one above the others, as shown in Figure 1. The polypropylene material is characterized with a dielectric constant of 2.6, conductivity of $0.11W/mK$ and loss tangent of 0.0003. The objective is to

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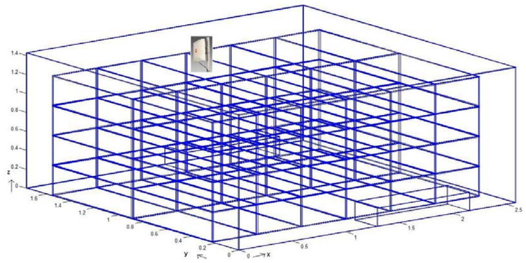

Figure 2. Scenario considered: indoor van full of buckets. The considered material for the buckets is polypropylene and the walls of the van are metallic.

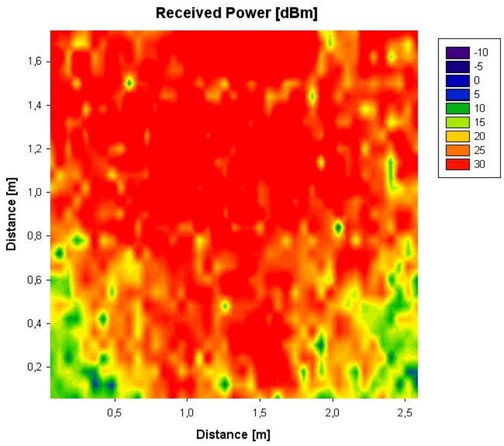

Figure 3. Received Power[dBm] at half height of the first line of buckets with circular polarized transmitter antenna and circular polarized receiver antenna.

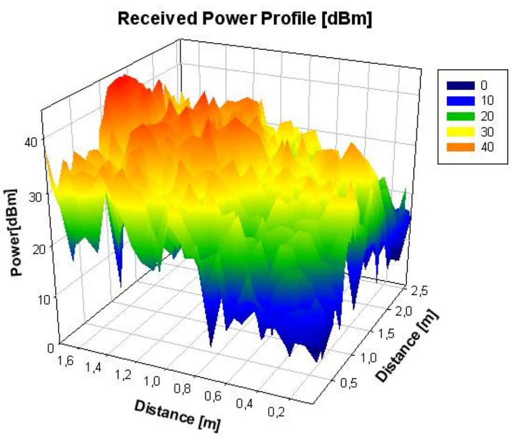

Figure 4. Received Power Profile [dBm] at half height of the first line of buckets with circular polarized transmitter antenna and circular polarized receiver antenna.

know how many buckets are within the closed vehicular environment every moment. To do this, each bucket is characterized with a RFID tag with sensitivity of $-65dBm$. The transmitter antenna is fixed at the point $(1.291, 1.762, 0.732)$m. The parameters used in the simulation are: cuboids resolution of 6cm, $\Delta\Theta = \pi/180$ and $\Delta\Phi = \pi/180$, seven rebounds and frequency of operation 860-960MHz (UHF-RFID Technology) with transmission rate of $106Kbps$ and power transmission of $26.9dBm$ $(500mW)$. Firstly, a circular polarized directional antenna is used for the transmitter, with $6dB$ of gain and horizontal beam width for $-3dB$ of 67º and vertical of 69º (Ref. Antenna PATCH-A0025). Then, a directional antenna with linear polarization is used, with a gain of $7dB$, and providing a 60º horizontal beam width for $-3dB$ and 74º vertical beamwidth (Ref. Antenna PATCH-A0026). For the receiver, a RFID generic tag is used, with an omnidirectional radiation pattern and both cases of polarization, circular and linear.

A. Transmitter antenna with circular polarization

Figure 3 and Figure 4 show the obtained results with the ray launching algorithm in 3D for the received power and the received power profile using circular polarization for the transmitter and receiver point. Figure 5 and 6 show the same results for a transmitting point of circular polarization and linear polarization at the receiver point. It is observed that the received power is greater in the first case, for circular polarization at the reception. This is because it is considered as receivers all the points in the space, and linear polarization at reception is not capturing all the received power.

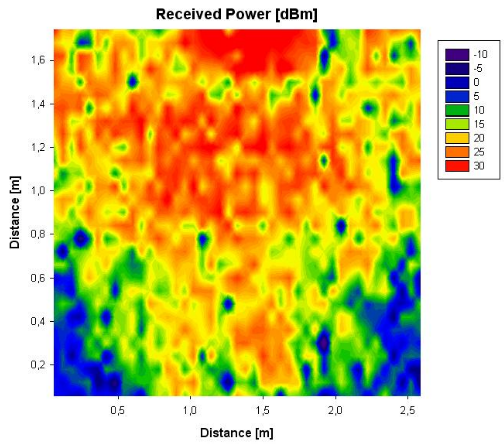

Figure 5. Received power [dBm] at half height of the first line of buckets with circular polarized transmitter antenna and linear polarized receiver antenna.

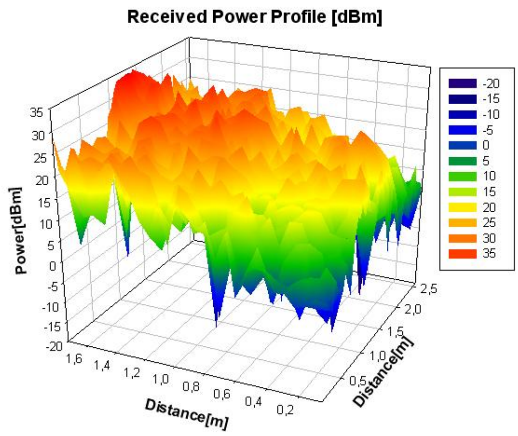

Figure 6. Received Power Profile[dBm] at half height of the first line of buckets with circular polarized transmitter antenna and linear polarized receiver antenna.

B. Transmitter antenna with linear polarization

Afterwards, the same simulations have been done with the ray launching algorithm, but changing the transmitting antenna by an antenna with vertical linear polarization. In the algorithm, the calculated electric field depends on the polarization of the transmitting antenna, and it is calculated taking into account the vertical polarization. Figure 7 and Figure 9 show the received power for the half height of the first line of buckets and Figure 8 and Figure 10 show the Received Power Profile.

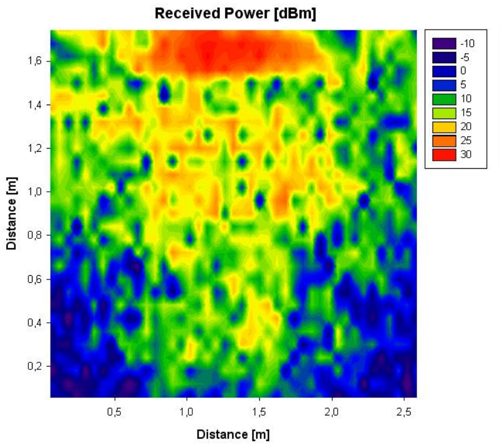

Figure 7. Received power [dBm] at half height of the first line of buckets with linear polarized transmitter antenna and circular polarized receiver antenna.

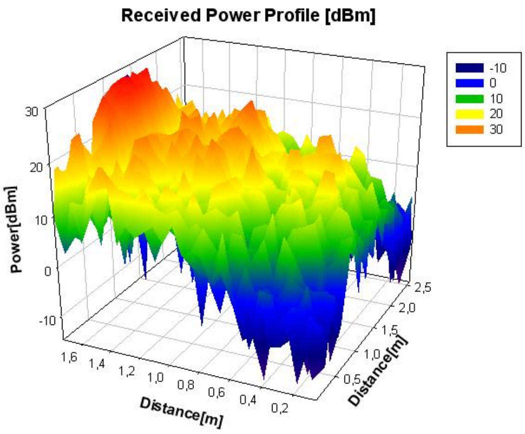

Figure 8. Received Power Profile[dBm] at half height of the first line of buckets with linear polarized transmitter antenna and circular polarized receiver antenna.

As it can be seen from both figures received power level is strongly dependent on the position of the potential receiver element and the greatest values of power are when the polarization of transmitting and receiving antenna is circular. For the other cases, no significant differences are observed in the received power. This is because the fundamental component in a closed metal environment is the multipath propagation, which is characterized by the temporal dispersion of the signal and the frequency dispersion due to temporal variations of the received amplitude [1].

Graphs of power profiles shows that the power decreases with distance with a lot of variability due to the number of multipath components located in this environment.

To illustrate the relevance in this propagation channel, the power delay profile for a scenario modeled as a cuboid has been predicted and is shown in Figure 7. As it can be seen, there is a large number of echoes in the scenario in a time span of approximately 5ns to 20ns, corresponding to distances from 0.015 meters to 0.06 meters, and which is coherent with the material properties and frequency of operation used in the vehicle.

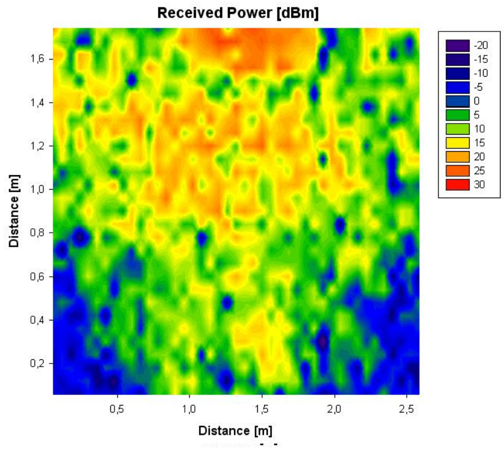

Figure 9. Received power [dBm] at half height of the first line of buckets with linear polarized transmitter antenna and linear polarized receiver antenna.

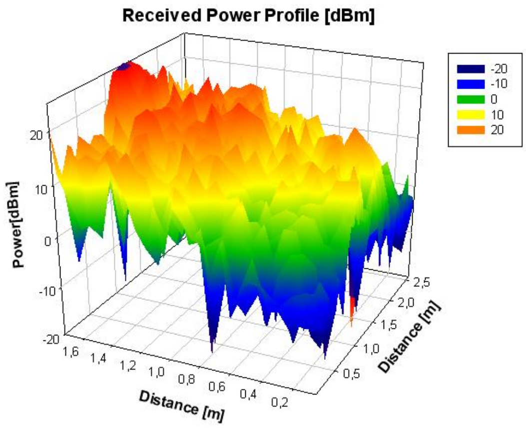

Figure 10. Received Power Profile [dBm] at half height of the first line of buckets with linear polarized transmitter antenna and linear polarized receiver antenna.

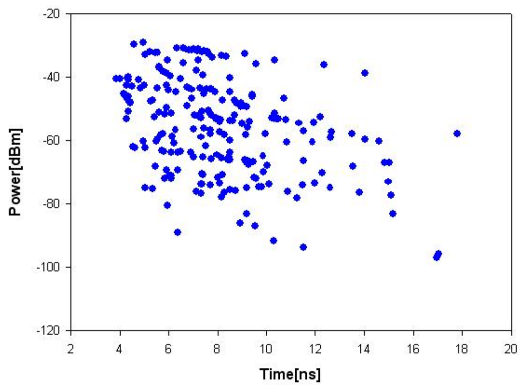

Figure 11. Power-Delay Profile at a given cuboid, located at the center (1.74m, 0.97m, 0.178m) in the indoor scenario.

III. CONCLUSION

In this work, the topological and morphological influence in the operation of a RFID system in a closed vehicle has been analyzed. The use of deterministic 3D ray launching in-house algorithm allows the optimization in the placement of sensors to improve the system efficiency and obtain a better signal quality. The results show that by considering radio planning issues in this considered scenario, the overall system performance can be strongly optimized.

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