FEKO™ Modeling Study of Passive UHF RFID Tags Embedded in Pavement

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***Abstract*—Radio frequency identification (RFID) is investigated as a technology that may be useful for smart cars and autonomous vehicles to read information about local road conditions and geographic location. Passive UHF RFID tags can transmit this data wirelessly to an RFID reader mounted on the vehicle. Coupling between a tag that is on or embedded in pavement, and the reader antenna mounted on the vehicles, is investigated by simulating the tag antenna, reader antenna and local environment in FEKO™. Preliminary simulation results show that it is feasible to implement such a system such that a vehicle traveling up to 200 km/hr. can read the tags as it passes over them.**

Keywords—Antennas, autonomous cars, navigation, propagation, RFID.

I. Introduction

We are close to the days when our cars will become completely autonomous and will not require human input for navigation. GPS is used to get geographical co-ordinates of the current location, and is the primary navigational guidance system for autonomous or self-driving cars, aided by local visual cues and vehicular radar. However, it is difficult to receive GPS signals in tunnels or in "urban canyons" surrounded by high-rises and construction [1]. The vehicle not knowing its precise geographical location and direction of travel for a brief moment of time can be dangerous. During these times RFID tags embedded into the road can provide the vehicle with specific data about the location [2]. Another problem autonomous cars have to deal with is the presence of temporary construction sites on roads. Signs are sufficient for a human driver to take a different path to avoid the area, but may not be sufficient for autonomous cars to make a navigation decision. Even though these cars can recognize road signs using various sensors, any distortion of the signs caused by weather, wear-and-tear, tampering, etc., can put these cars into confusion. Human intervention is still required to maneuver the car in such situations.

Existing RFID technology can help vehicles obtain more information about the local environment. RFID tags can be embedded on the surface of the road or under the first layer of pavement, and the vehicles passing above them with an RFID reader can interrogate the tags and download the information embedded on the tag or associated with the tag ID number. Certain information can be stored directly in the RFID tag's chip, but as discussed in [1], if this is not enough we can rely on a database system where the data can be retrieved via cellular communication from a database which will have a list of tag IDs and their corresponding data. The advantage of this system is that the data may be updated as road conditions or construction areas change.

The two key issues to be investigated to make a passive UHF RFID system for roads feasible are: 1) read range, and 2) time to read the tag. RFID chips take time to communicate with the reader and this puts a constraint on the speed of the vehicle trying to read the information from the tag. The read range is important because a longer read range means the reader will have more time to communicate with a given tag. These two interdependent issues are investigated here using Altair's FEKO™ computational electromagnetics simulation software.

Section II describes the simulation setup and assumptions made, including information on the reader antenna, the tag antenna, their orientation, and the electrical characteristics of the materials used for simulating the pavement. Section III presents the results obtained from the simulation study and Section IV discusses conclusions on the feasibility of and RFID road system. It also discusses the limitations of the current simulations and proposes future work for improving the simulations and implementation of the system.

II. Simulation Setup

Fig. 1 shows the geometry of a linearly polarized rectangular patch antenna for 915 MHz used as the reader antenna. It is excited by a wire port in FEKO. Most commercially available UHF passive RFID tag antennas have a dipole-like structure and a dipole like gain pattern, hence a small wire dipole antenna matched at 915 MHz is used in the simulations to represent an RFID tag. A single layer 22 cm thick dielectric is used to model the road. Concrete and asphalt roads are chosen for the simulations. The concrete is chosen from the media library of FEKO. The electrical characteristics of asphalt are chosen as follows: permittivity = 6, conductivity = 10^{-4} S/m, and mass density = 2322 kg/m^3 [3]. These parameters represent dry asphalt. The reader antenna facing downward is kept 35 cm above the road. Simulations were performed for tags on the surface and embedded 3 cm into the road. The dipole antenna is oriented to match the polarization of the patch antenna (X-polarized in Fig. 1). Each antenna has a port assigned. The patch

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antenna is the active port with 1 W of radiated power.

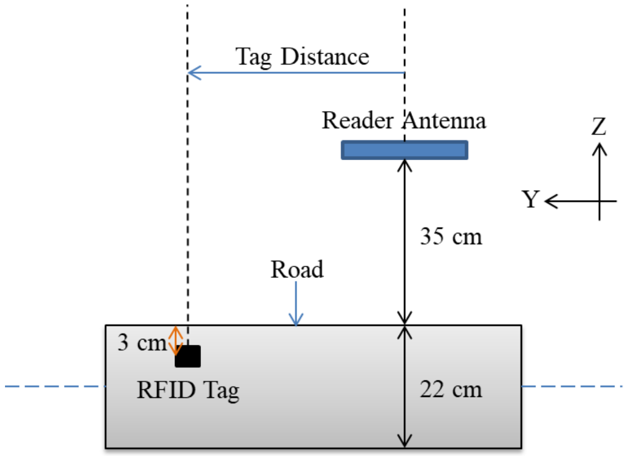

Fig. 1. Side view of the simulation setup. The pavement is infinite in the X and Y directions. The RFID tag antenna and reader antenna are linearly polarized in the X direction.

III. RESULTS

For successful communication between the tag and the reader, a certain amount of RF power must be delivered to the passive RFID tag by the reader antenna. The threshold power for activating the chip is usually specified in the data sheet. For the Impinj Monza 2 RFID chip it is -11.5 dBm (decibels relative to a mW). 1 W of power is fed into the reader antenna, hence the S_{21} between the two ports of the antennas, the wire dipole and the patch antenna, tells us the amount of power received by the wire dipole representing the RFID tag. It is noted that normally the tag antenna is matched to the impedance of the RFID chip, but that is not necessary for the power transfer computations presented here. The tag is moved horizontally away from the reader antenna along the Y-axis in steps of 10 cm. The corresponding S_{21} is computed. The distance where the power reaching the tag falls below the -11.5 dBm threshold is important because this is where the chip will not be activated. Multiplying this distance by two (symmetry on both sides of the Z-axis) gives us the total length of the zone over which the reader can successfully communicate with the tag (because in this zone it is able to deliver sufficient power to the chip for communication). The power delivered to the tag as a function of the Y-distance is plotted in Fig. 2.

According to Chon et al. [1], for successful communication between a tag and a reader, 18 ms are required for transferring 128 bits of data (such as the tag ID number). So the tag and the reader have to be in communication range for at least 18 ms. If we consider a vehicle travelling at 200 km/hr., then in 18 ms it travels 1 m. So the range over which the reader transfers threshold power to the tag should be at least 1 m. We can calculate the communication range for each scenario plotted in Fig. 2 by multiplying by two the distance where the power reaching the tag goes below -11.5 dBm. For example, the communication zone for a tag embedded 3 cm below the concrete pavement is 2 times 50.76, or 101.52 cm. Since this is more than 1 m, all the vehicles travelling at speeds up to 200 km/hr. should be able to successfully communicate with the tags on the road. The communication ranges for the other cases are higher than the one we considered above since the threshold power reaching the tag goes below -11.5 dBm over a greater distance than 50.76 cm. Hence, vehicles travelling at speeds up to 200 km/hr. will certainly be able to communicate with the tags embedded in the roads under the assumed conditions.

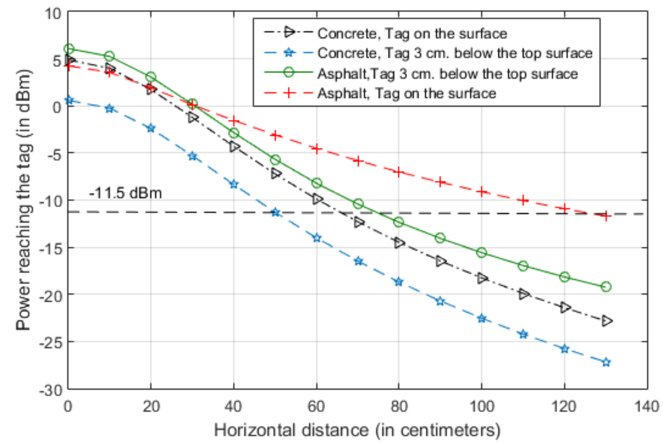

Fig. 2. Power received by the tag antenna as a function of the horizontal distance from the reader antenna for tags on or inside concrete and asphalt pavement. The threshold power of -11.5 dBm is required to activate the RFID chip.

IV. CONCLUSION

Preliminary simulations show that implementing a passive UHF RFID system for concrete or dry asphalt pavement is feasible. The vehicle will not always travel directly over the tag, so more than one reader antenna should be used to make sure that the reader doesn't miss any. Multiple reader antennas are typically connected to a single reader to provide spatial diversity in UHF RFID systems. Placement of these extra antennas will be investigated in the future, as well as various positions and orientations of the tags on the roads. Most importantly, rain, ice and snow will most certainly affect the communication range of the tag and the reader. Therefore, these conditions should be carefully studied in future simulations and experiments.

REFERENCES

[1] H. Chon, S. Jun, H. Jung, and S. An, "Using RFID for accurate positioning," Journal of Global Positioning Systems, vol. 3, no. 1-2, pp. 32-39, 2004.

[2] T. Jing, X. Wei, W. Cheng, M. Guan, L. Ma, Y. Huo, and X. Cheng, "An efficient scheme for tag information update in RFID systems on roads," IEEE Transactions on Vehicular Technology, vol. 65, no. 4, pp. 2435-2444, 2016.

[3] O. Franek, P. Kyritsi, and G. F. Pedersen, "RFID on the road – some considerations about passive tag antennas," in Proc. 5th EuCAP, Rome, Italy, pp. 1203-1207, Apr. 2011.