On-road Slot Antenna with Corrugated Ground for Road-Curtain Machine-to-Machine RFID Application

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***Abstract*— A novel slot antenna designed on the road surface for machine-to-machine (M2M) RFID communication is presented. A corrugated ground plane with perturbed surface impedance is used underneath the antenna's radiator to adjust the antenna's radiation pattern, which otherwise will be highly affected by the properties of the road surface. The proposed antenna configuration is verified by full-wave simulations with various road surface conditions. The results show that the antenna has a stable performance with different road conditions. It possesses more than 12 dB return loss, more than 1.4 dBi gain, vertical polarization, and desirable radiation pattern from 880 MHz to 960 MHz.**

Keywords*— On-road communications, low-profile antenna, UHF angtenna, slot antenna, corrugated ground.

I. INTRODUCTION

Ultra-high frequency (UHF) passive RFIDs, specifically GS1-G2V2 and its parallel ISO/IEC 18000-63 type C protocol, are commercially used to identify vehicles in electronic toll and vehicle access control [1]. The conventional utilization requires a RFID tag affixed on the inner side of the vehicle's windscreen and the readers to be installed on an overhead structure, such as a gantry, above free flow roads. However, the placement of the windscreen tags remains a challenge due to the variation in the dielectric parameters and thickness of different windscreens [2]. Moreover, tinting of the windscreen and/or the post fitment of heat protective layers results in a conductive layer in or on the glass, which limits the performance of the tag antenna beyond the point where it can be used for a successful detection [3]. In these identifications even a small percentage of false negative identification may lead to additional policing cost and reduction in the effectiveness of law enforcement. Also, from observation of toll gantry distributions, it seems that overhead placement of readers on gantries have both a deployment and maintenance costs, which limit the density of such deployments to a sparse placement on motorways.

In [4], it was concluded that placing the RFID tag on the vehicle licencing plates might be a more reliable option specifically that it is compulsory that all vehicles of a national fleet must be fitted with such plates. Vehicle license plates are commonly manufactured from a metal base; thus they are easy to be integrated with an RFID-enabled on-metal tag. To avoid gantry construction and the associated costs, an on/in road RFID reader (so called a RoadCurtain reader) is considered, as illustrated in Fig. 1. The antenna installed on the proposed reader must not protrude higher than 5.0 cm [5] above the road surface and its radiation pattern needs to ensure that the tag can be identified in the reading zone. A linear polarization on vertical plane (perpendicular to the ground) is required to be generated from reader antenna in order to match the polarizations on tag. Also, for the purposes of easy and cost-efficient installation, the footprint of the RoadCurtain reader should be no more than $30cm \times 30cm$.

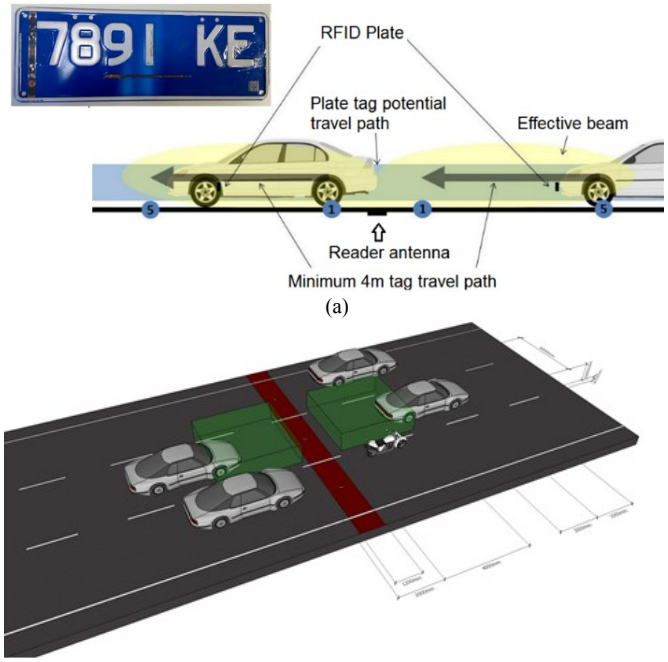


Fig. 1 (a) Schematic diagram of RoadCurtain reader communicating with RFID-enabled license plate embedded with a grooved slot, and (b) architecture of on-road antenna, where, the reading zone is highlighted.

To date, there is a limited number of UHF antenna types that is suitable for the proposed RoadCurtain application. The prototype presented in [6-7] were designed to operate at free-space; their radiation and impedance-matching properties may significantly downgrade if put on the high-permittivity road surface. In a more recent development, the company Impinj® [8], has developed an UHF antenna to work on the road surface; however, their physical dimensions and radiation patterns do not meet the desired engineering requirements specified for the Road Curtain system. Furthermore, due to the road conditions change with weather where the road may be very dry or wet, it

is a challenge task to design an efficient reader antenna adapted to operate under all circumstances.

In this paper, an on-road UHF slot antenna that works at the RFID band 920 MHz is presented. A corrugated ground plane with perturbed surface impedance is used underneath the antenna's radiator to improve and stabilize the antenna's radiation pattern to limit its variation with the properties of the road surface.

II. Antenna Design

In light of the aforementioned design criteria, a rectangular slot radiator mounted on a corrugated ground layer is proposed. The antenna shown in Fig. 2 is designed to operate at the centre frequency f_0 =920 MHz, which is licensed for this application. A 50-ohm lumped excitation port via the offset position on the slot is utilized as the feeding structure. Full-wave finite element method (FEM) simulator, ANSYS HFSS is utilized to calculate and optimize the performance of the proposed design. The road structure underneath the antenna is modelled in the simulator as a layered-impedance boundary condition with average permittivity and conductively values of $\epsilon_r = 3.5$ and $\sigma = 0.01$ sig/m respectively [9].

The slots engraved on the radiator are of symmetrical tapered structure, which is used to increase the bandwidth of impedance matching. A periodic corrugated ground structure underneath the radiator is mounted to generate an artificial electromagnetic soft-surface [10], which is employed to suppress the surface wave and inhabit any significant energy from propagating towards the road surface. Also, it helps to reduce the footprint of the antenna. The design parameters of the optimized antenna structure are shown in Table. I.

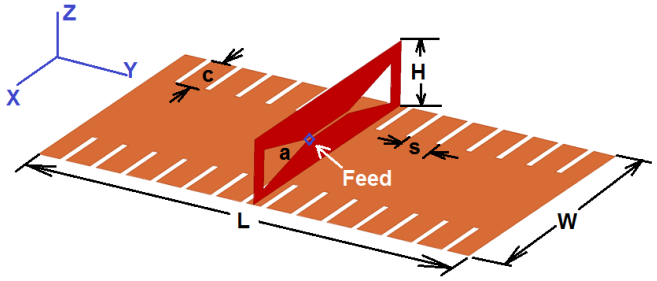


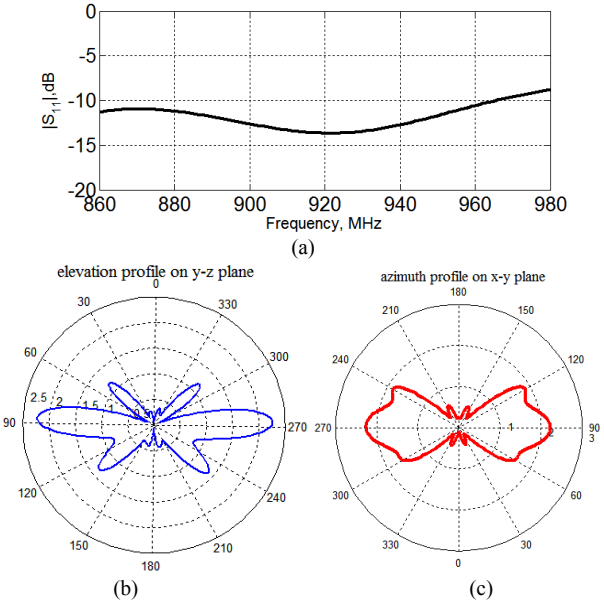
Fig. 2 Slot antenna with corrugated ground plane on the road surface.

Table. I Design parameters of the optimized antenna structure

Design Parameter	Description	Value
L	Length of ground	300 mm
W	Width of ground	180 mm
H	Height of radiator	43 mm
C	Length of corrugated slot	40 mm
S	Spacing of periodic corrugate	21 mm
a	Angle of tapered slot	20 degree

III. Simulation Result

The simulation results of the proposed slot antenna are shown in Fig. 3. More than 12 dB return loss is achieved over the frequency band from 880 MHz to 960 MHz. The simulated radiation properties indicate more than 1.4 dBi gain with pure-vertical polarization. Thus, a desirable radiation pattern is generated using a low profile antenna that ensures a successful reading of the tag, located within the vehicle's license plate, by the reader RFID over the reading zone.



(a) (b) (c)

Fig. 3 Simulation results of the slot antenna at 920 MHz. (a) Reflection coefficient, (b) radiation pattern on E-plane (elevation profile on y-z plane), and (c) radiation pattern on H plane (azimuth profile on x-y plane).

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References

[1] GS1 EPC/RFID UHF Class 1 Gen 2 Version 2, EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID – Specification for RFID Air Interface – Protocol for Communications at 860 MHz – 960 MHz, GS1

[2] ISO/IEC 18000-63, Information technology -- Radio frequency identification for item management -- Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C, International Standards Organisation

[3] EN 1463-1:2009, Road marking materials – Retroreflecting road studs, European Committee for Standardization

[4] B.Pretuorius, Y. Wang, A. Abbosh, S. Saario, 2014, An Antenna, Australia Patent 2014902707

[5] B.Pretuorius, 2015, On-road UHF RFID Traffic System, Australia Patent PCT/AU/2015/050161

[6] Berge, L.A.; Reich, M.T., "A UHF RFID antenna for a wireless sensor platform with a near-isotropic radiation pattern," , IEEE International Conference on RFID., pp.88,95, 2013

[7] Serkan Basat, S.; Bhattacharya, S.; Li Yang; Rida, A.; Tentzeris, M.M.; Laskar, J., "Design of a novel high-efficiency UHF RFID antenna on flexible LCP substrate with high read-range capability," IEEE Antennas and Propagation Society International Symposium, pp.1031,1034, 2006

[8] http://www.impinj.com/products/readers/speedway-antennas/

[9] http://www.kayelaby.npl.co.uk/general_physics/2_6/2_6_5.html

[10] Kildal, P.-S., "Artificially soft and hard surfaces in electromagnetics," Antennas and Propagation, IEEE Transactions on , vol.38, no.10, pp.1537,1544, Oct 1990