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Investigation of optical wireless for employment within a vehicular environment

Zaiton Abdul Mutalip

A thesis presented for the degree of

Doctor of Philosophy

School of Engineering

March 2016

To my family, for their unconditional support

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Acronyms

CAN	Controller Area Network
DD/IM	Direct Detection / Intensity Modulation
DH-PIM	Double-Pulse Interval Modulation
DPIM	Digital Pulse Interval Modulation
DPPM	Differential Pulse-Position Modulation
ECU	Electronics Control Unit
EM	Electromagnetic
FM	Frequency Modulation
FOV	Field of View
IrDA	Infrared Data Association
IRLED	Infrared Light Emitting Diode
LAN	Local Area Network
LED	Light Emitting Diode
LIN	Local Interconnect Network
LOS	Line of Sight
MAC	Medium Access Control
MOST	Media Oriented Systems Transport
MSM	Multiple-Subcarrier Modulation
NLOS	Non Line of Sight
OOK	On Off Keying
SNR	Optical Signal to Noise Ratio
OW	Optical Wireless
OWC	Optical Wireless Communication

PM	Pulse Modulation
PPM	Pulse Position Modulation
RF	Radio Frequency
RFID	Radio-Frequency Identification
RMS	Root Mean Square
RZ	Return to Zero
SNR	Signal to Noise Ratio
SSM	Single-Subcarrier Modulation
TDMA	Time Division Multiple Access
TTP	Time-Triggered Protocol
TTCAN	Time-Triggered CAN
UWB	Ultra-Wide Band
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle

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Declaration

This thesis is submitted in partial fulfilment for the degree of Doctor of Philosophy under the regulations set out by the Graduate School at the University of Warwick. This thesis is solely composed of research completed by ZAITON ABDUL MUTALIP, except where stated, under the supervision of Professor Roger J. Green, Dr Mark S. Leeson and Dr Matthew Higgins, between the dates of January 2012 and March 2016. No part of this thesis has been previously submitted to the University of Warwick or any other academic institution for admission to a higher degree.

Zaiton Abdul Mutalip
March 2016

Abstract

The substantial increase in powerful electronic systems and functions has produced significant implications for the vehicular industry, where the amount of wiring infrastructure has increased the vehicle weight, weakened performance, and made adherence to reliability standards difficult. Eventually, connecting the electronics infrastructure was mostly complicated and costly in vehicular domain systems. Thus, little research has been conducted to explore appropriate wireless technologies that may be suitable with the emerging network standard within the context of vehicular networks.

This thesis describes an in-depth investigation of deploying an optical wireless communication system within the vehicular environment, particularly in confined spaces. A wide variety of measurements has been performed using tubes of various materials and geometries, in a laboratory setup. The principle objective is to provide a primary knowledge of optical wireless channel characterization within a laboratory vehicular setting. The work presented is a study on directed line-of-sight (LOS) and non-LOS (NLOS) links, and focuses on frequency response, power efficiencies, and path losses in different experimental settings. Further, a variety of experimental settings was used in respect to different receiver/transmitter orientations and various bent tubes angles in order to investigate the channel conditions. The noise analysis,

SNR, path loss and the eye pattern for the digital system prototype designed were also analysed.

The system requirement for the LOS link were based on the transmission of the sinusoidal signal at a distance of 1 m with 13 MHz signal and approximately 15.6 dB SNR. Successful demonstration of the OWC within smaller size and high reflection coefficient material are promising. In addition to good transmitter and high sensitivity receiver.

The NLOS link also demonstrated a good indication, both in straight tube with angled transmitter/receiver orientation and bend tubes. Detail studies on NLOS link with pulse signal transmission, which replicates a digital system transmission with 54.48 mW or 44.58 mW/cm^2 output power,6 MHz signal transmission with the aim of 10^{-4} to 10^{-6} BER. Although, the operational functionality of digital system has successfully demonstrated, however achieving the desired BER is a bit difficult with the designed system. Further improvement on the highly sensitive receiver design, a proper modulation scheme is required in order to improve the quality of the transmitted signal in terms of SNR and BER.

The study also suggested that the transmission within the metal tubes is better than in plastic tubes in addition to minimum bend angle, smaller tube diameter and high reflective coefficient. Transmission within 20 mm circular aluminium tube and 35 mm galvanised aluminium tube are the best so far.

Finally, based on the initial viability results, it was seen that it is possible to implement an optical wireless communication infrastructure within the vehicular environment. Experimental validation of the system proposed shows that achieving high data rates is not a problem with the use of high brightness, high power LEDs as this system is

going to be implemented within the vehicle chassis, thus the eye safety constraints should not be a limiting factor. Therefore, in this study, optical wireless transmission within the vehicular environment is proposed, solving the problems of vehicular networking systems.

Publications associated with this research work

The following papers have been published as a result of the work contained within this thesis.

Conference Paper

R. J. Green, Z. Rihawi, Z. A. Mutalip, M. S. Leeson, and M. D. Higgins, “Networks in automotive systems: The potential for optical wireless integration,” in Transparent Optical Networks (ICTON), 2012 14th International Conference on, 2012, pp. 1–4

Book Chapter

M. D. Higgins, Z. Rihawi, Z. A. Mutalip, R. J. Green and M. S. Leeson, “Optical Wireless Communications in Vehicular Systems”, Communication in Transportation Systems, O. Strobel (ed.), IGI Group, ISBN 978-14-666-2976-9, Chapter 7, pp. 209-222, 2013.

Journal Paper

Z. S. Rihawi, Z. A. Mutalip, M. S. Leeson, M. D. Higgins and R. J. Green, “Free Space Optical Communications in Vehicular Networks Using Rectangular Guiding Models”, Photonics Technology Letters, vol. 28, no. 13, pp. 1430-1433, 2016.