Visible Light Communication System for Indoor Positioning Using Solar Cell as Receiver

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ABSTRACT

This article studies an indoor positioning system (IPS) based on visible light communication (VLC) using the solar cells as optical receivers. Due to the solar cell characteristics, the proposed system offers simultaneously communication and energy gathering. The current - voltage (I-V) and power - resistor (P-R) curves of solar cell under visible light is studied. The frequency response is investigated. The effect of solar irradiance interference on the VLC-based indoor positioning system (VLC-IPS) efficiency is also shown. A trilateration technique is used for estimating receiver’s location. The obtained results show that the proposed system can simultaneously receive data and collect energy and it provides a suitable positioning accuracy with an average position error less than 3cm. The studied system can be considered an eco-friendly and promising technology.

KEYWORDS


INTRODUCTION

The operation of positioning people and objects has always been important and will be more important in the next years. However, there exist two categories of positioning systems: Outdoor and Indoor.

Global Positioning System (GPS) is well known for outdoor positioning estimation. But because the influence of multi-path or radio disturbance inside buildings it is hard for GPS to supply accurate location information to users (Won et al., 2013). Due to this inconvenient, a lot of methods to achieve indoor positioning are made. Some of these methods are based on infrared or ultrasonic, radio-frequency and Wi-Fi where a large error distance range from centimeters to meters are given (Yang et al., 2012). Elsewhere, in literature (Zhou, Kavehrad, & Deng, 2012) there are mainly three mathematical techniques with their algorithms used in wireless Indoor Positioning Systems (IPS), these principles are: proximity, triangulation and scene analysis. Triangulation is based on the knowledge of geometric properties of triangles to determine the target location. This technique consists of two branches: Lateralation and Angulation. Trilateration technique which is used in this paper to determine the target location by measuring its distance from multiple points with known coordinates called reference points (Hassan et al., 2015). With the evolution of the bulbs the Light Emitting Diode (LED) appeared like a best alternative of the traditional lamps due to its ability to deliver a communication

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signal. The technology which uses LED light in the wireless optical communication is called Visible Light Communication (VLC) (Xu et al., 2016). It is a recent technology to detect targets in indoor environment, where it’s very remarkable as a new type of wireless communication technology with less energy consumption and it has many advantages such as: it is free, has large bandwidth, high security and environmentally safe (O’Brien et al., 2008; Jovicic, Li, & Richardson, 2013; Hassan et al., 2015). In addition, the no affected to Electromagnetic Interference (EMI) allows VLC to be applied in many sectors like hospitals, airplane, smart cities, smart homes and offices, etc, where the Radio Frequency (RF) communication is in interference with equipment’s signals. Hence, VLC has attracted many interests recently (Komine & Nakagawa, 2004; Afgani et al., 2006; Vucic et al., 2010; Chow et al., 2012). Using VLC in Indoor Positioning Systems (IPS) is a potential energy-efficient and low-cost solution for wireless communication of consumer electronics and improves the accuracy of positioning. Classical receivers used in VLC systems are (PIN) Photo-Diode (PD) or Avalanche Photo-Diode (APD) (Jung et al., 2013; Won et al., 2013; Yang et al., 2012; Zhou, Kavehrad, & Deng, 2012). The drawback of this type of active receivers is the lack of energy efficiency. The advantage of using solar cell is self-powered VLC receiver. Furthermore, VLC-based IPS do not require high speed VLC signals (Zhou, Kavehrad, & Deng, 2012; Jung, Lee, & Park, 2014).

The worldwide solar cell technology is rapidly developed due to the efforts of researchers to increase the efficiency (Fraas & Partain, 2010; Abbott, 2010). Even, solar cells are widely used in many applications like solar phone charges, solar flash light and calculator, etc... (McEvoy, Castaner, & Markvart, 2013; Green, Emery, Hishikawa, Warta, & Dunlop, 2013). As it is-known solar cell is mostly used to harvest solar power (Danesh & Long, 2011; Lee, Kim, & Lee, 2010) but it has also an important role in receiving a wireless optical signal (Wang, Tsonev, Videv, & Haas, 2014).

Energy harvesting and signal detecting system is a new conception which was proposed by (Wang, Tsonev, Videv, & Haas, 2015) as a VLC system with solar-panel receiver; also in (Kim, Won, & Nahm, 2014), they used a solar cell as simultaneous receiver for solar power and visible light communication (VLC) signals, where they used it in data transmission. The authors in this paper focused on using solar cells in indoor positioning system. They use trilateration technique and exploit the ID signal.

Besides, the modulated VLC optical signal can be converted into electrical data signal by the solar cell arrays or solar panels receiver (Rx), without adding any external power. This electrical signal can be used to fill the battery of the receiver. It should be noted that the silicon-based solar cells can receive VLC data and recover energy at the same time.

In this work, to locate the receiver the authors used trilateration technique and in order to estimate the receiver’s distance from transmitters on the ceiling the information from the received ID signal is used. Unlike conventional VLC positioning system, a solar cell is used as a positioning receiver. The Field Of View (FOV), light sensitivity and detection area are significantly enhanced compared to the performance of PIN Photo-Diode (PD). In addition to needless of external power supply, it can provide energy efficiency to the receiver side (Liu et al., 2016). This work can be exploited for asset and people tracking in several indoor sectors as tracking patients in hospitals or security guards in malls. A study of Current - Voltage (I-V) and Power - Resistor (P-R) curves of solar cell under visible light is done to prove the ability of solar cell to receive simultaneously solar power and VLC signals. Then, the frequency response is investigated to show the limitation of using higher frequencies in the system. The effect of solar irradiance interference on the VLC-based IPS efficiency is done. Furthermore, by using the identity positioning technique hence using the ID of each LED to define every positioning area, the target can be traced. A similar model to the real lighting conditions is solved using MATLAB simulations. The results indicate that solar cell is able to receive data and collect energy at the same time. Also, a suitable positioning accuracy was achieved.
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