Faculty of Engineering **Tanta University**

Electronics and Communications Engineering Department

"Performance Evaluation of Free Space Optical Communication Systems under the Impact of Ionizing Radiation"

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Abstract

This study evaluates the implementation and performance of a Visible Light Communication (VLC) system designed to transmit text data between two personal computers (PCs). The proposed system utilizes three distinct light-emitting diode (LED) —Single LED, 2×2 LED Array, and 4×4 LED Array—as transmitters and three types of photodetectors—BPW34 photodiode, solar cell, and light-dependent resistor (LDR)—as receivers. Controlled by an Arduino, the system investigates the relationships between data rate, transmission distance, beam angle, LED configurations, and detector types. Experimental results confirmed that the BPW34 photodiode outperformed the solar cell and LDR in terms of maximum achievable data rate and transmission distance, consistent with its superior bandwidth and sensitivity characteristics. The findings also reveal that, at a zero-degree beam angle, the system employing the BPW34 photodiode achieved a maximum transmission distance of 9.15 meters at 1 kilobit per second (kbps) with a single LED configuration, diminishing to 1.24 meters at 4 kbps. The 2×2 LED array extended the distance 14.20 meters at 1 kbps and 2.30 meters at 4 kbps. Conversely, the 4×4 LED array exhibited the most extensive propagation distances, achieving 16.30 meters at 1 kbps and maintaining 3.25 meters at 4 kbps. These findings underscore the efficacy of increasing LED array size in enhancing propagation distance, particularly at lower data rates. The study highlights the potential of VLC systems

for efficient indoor optical communication, providing valuable insights for optimizing LED configurations and receiver technologies in future applications.

This research presents an extended performance analysis of an indoor Visible Light Communication (VLC) system by integrating experimental results with advanced GEANT4 simulations. Building on a prior empirical study that evaluated different LED configurations and photodetectors, this work explores critical environmental and spatial parameters that influence VLC efficiency and reliability. Parameters such as wall reflectivity, emission angles, photon energy, and photon travel time are systematically analyzed using a validated GEANT4 simulation framework. The results confirm the strong impact of narrow emission angles and high wall reflectivity on detection performance, while also highlighting the importance of time delay modeling in high-fidelity simulations. Energy deposition was realistically correlated with photon count and energy levels, offering valuable insight into detector response and system thermal behavior. This study demonstrates the robustness of combining experimental insights with physics-based simulation, thereby offering a comprehensive and realistic perspective for designing optimized VLC systems in complex indoor environments.