Abstract

Optical wireless communication (OWC) is a promising alternative solution to tackle the issues of spectrum scarcity and traffic congestion. The term OWC is defined as the transmission in an unguided propagation medium using optical carriers in the visible, infrared, and ultraviolet frequency bands. Outdoor terrestrial or free space optical (FSO) communication is one of the categories of OWC, which deals with the data transmission between two fixed points over several kilometers using optical carriers. FSO communication systems have many advantages, such as huge license-free bandwidth, high data rate, low latency, cost-effectiveness, and quick deployability. Despite the aforementioned merits, the performance of FSO systems is limited by atmospheric turbulence (AT), pointing errors (PEs), path loss, geometric loss, and background radiation. Conventionally, FSO systems utilize intensity modulation/direct detection (IM/DD) due to the low cost and ease of implementation; on the other hand, the heterodyne detection (HD) technique has a higher cost and is relatively difficult to implement, but it provides improved communication performance. FSO communication is inherently more secure than radio frequency (RF) communication because the optical beams are more directional than the RF beams, thus FSO communication systems are less subject to eavesdropping/intercepting. However, optical beams can still be intercepted particularly when the eavesdropper is close to the legitimate receiver or lies within the divergence angle. In recent years, the research on secrecy performance analysis has increased significantly. We evaluate the exact closed-form expression of the average secrecy capacity (ASC) and secrecy outage probability (SOP) under the composite effect of the generalized Malaga distributed AT and non-zero boresight PEs in this thesis. Through the detailed asymptotic analysis, it is revealed that the secrecy diversity order depends on the minimum of the main link parameters of the FSO system for the respective detection technique (HD or IM/DD).

We incorporate hybrid-automatic repeat request (H-ARQ) in the FSO communication systems to improve their performance and communication link reliability. H-ARQ technique combines strong channel coding with retransmission request protocols to improve FSO system reliability. We derive novel closed-form expressions for the outage probability of the FSO systems under the combined impact of Gamma–Gamma distributed AT and PEs for HD and IM/DD techniques. We compare the FSO system performance for different H-ARQ protocols, such as at least once (ALO), chase combining (CC), and incremental redundancy (INR). Further, we calculate throughput for the FSO systems by utilizing outage probability expressions for the mentioned H-ARQ protocols. We also conduct an extensive asymptotic analysis for different H-ARQ protocols which reveals that the achieved diversity gain is the product of the number of transmission rounds and the minimum of the link parameters for the respective detection technique.

To further enhance the FSO system coverage, we consider a mixed dual-hop FSO-RF communication system. The considered dual-hop FSO-RF communication system serves the end user via a decode and forward (DF) relay employing H-ARQ protocols on both hops. The intelligent reflecting surface (IRS) has been utilized on RF links for their merits, such as the capability to provide greater coverage, improved spectrum, and energy efficiency. We derive the outage probability and packet error rate (PER) of the proposed system by considering generalized detection techniques such as HD and IM/DD on the source-to-relay ($S-R$) link with H-ARQ protocol and IRS having phase error. The inclusion of IRS phase error in our analysis is essential for closely emulating a practical system model.

To obtain more fruitful insights into the FSO communication systems, we develop an experimental setup of a 10 Gigabits/second (Gbps) FSO communication system in a

laboratory-controlled environment. An AT chamber is designed to introduce the effects of turbulence, fog, and heat onto the transmitted signal. We experimentally evaluate the bit error rate (BER) and the received power profile fluctuations in the presence and absence of AT. Further, we also demonstrate the effect of heat and fog on the received power profile. Additionally, we exemplify the role of cyclic redundancy check (CRC) to mitigate the deteriorating effects of atmospheric conditions on the FSO link. We found that the BER values of approximately 4×10^{-8} at received powers of -19.29 dBm and -16.98 dBm are achieved for the framed and the unframed data, respectively, and the power gain is around 2.31 dB. This experimental result demonstrates that the BER performance of FSO systems can be improved with the use of CRC bits.