Thesis Title: ANALYTICAL AND EXPERIMENTAL EVALUATION OF FREE-SPACE OPTICAL SYSTEMS WITH CHANNEL CORRELATION

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Abstract of Thesis: With the tremendous demand and the ever-increasing popularity of data-based internet usage owing to the various technological innovations such as 5G, the internet of things, virtual reality, over the top streaming, etc., wireless communication (WC) has undoubtedly become an integral part of our life. Because of this, the radio frequency (RF) spectrum has become highly congested, and it has become evident that the RF spectrum will not be sufficient to meet the future demands of WC. For future-proofing of the WC, optical WC (OWC) has emerged as a viable complementary technology to the existing RF and fiber-based technologies. OWC is a health-friendly technology that transmits data over free-space using the optical spectrum, which has an abundance of unregulated bandwidth. Free-space optical (FSO) communication is a long-range terrestrial OWC, that uses the infrared spectrum for data transmission. Similar to the RF systems, improved performance can be achieved in FSO systems also by using spatial diversity techniques with multiple transmit and/or receiving apertures. However, due to the limited available space at most of the practical FSO transceivers, the realization of multiple apertures-based FSO systems in practice makes the spatial correlation inevitable.

The work presented in this thesis unfolds the impact of channel correlation on the performance of spatial diversity-based FSO systems employing the widely used modulation and coding schemes. The investigation is carried out both analytically and experimentally. The analytical study is based on various performance metrics such as bit error rate (BER), outage probability, and capacity. Repetition coding (RC) is used as a spatial diversity technique to achieve an improved system performance in presence of atmospheric turbulence (AT). The first part of this work assumes that the transmit apertures are equidistant and arranged in a manner that results in an FSO channel with constant correlation. The Gamma-Gamma ($\Gamma\Gamma$) distribution with a constant correlation is used for the statistical characterization of the FSO channel. A thorough analysis of the system performance is carried out for on-off keying modulation by deriving a few important parameters such as BER, diversity order, and coding gain as a function of correlation and signal-to-noise ratio. It is observed by simulation and analysis that the correlation does not affect the

diversity order of the considered FSO - multiple-input single-output system with RC, however, it significantly abases the coding gain of the system.

In order to consider a generalized FSO system, this thesis presents the derivation of a novel joint probability density function of generic Malaga ($\mathcal{M}$) distribution with arbitrary correlation. The derived distribution is valid for an arbitrary correlation model, applicable to all the AT regimes, and can also be mapped to most of the existing distributions. The derived result is used for the outage performance analysis of a single-input multiple-output FSO system with selection combining.

Further, this thesis explores optical spatial shift keying (OSSK) as a modulation technique with improved spectral efficiency and reduced decoding complexity for a correlated FSO multiple-input multiple-output (MIMO) system. The effect of correlation on the performance analysis of an FSO-MIMO system with OSSK is studied in terms of BER, capacity, diversity order, and coding gain. All the analytical results are validated using MATLAB simulations. Experimental setup of FSO system with two correlated links is also designed to study the throughput and latency of the system at different turbulence levels.

Finally, for a more practical study, this thesis investigates the BER performance of an FSO-MIMO system employing RC for a correlated channel in presence of amplified spontaneous emission noise. The analytical findings are substantiated by developing an experimental set-up of a 2×1 correlated FSO system with RC in the presence of a pre-amplifier at the receiver for the BER study.