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Comparison of Laguerre-Gaussian and Donut modes for MDM-WDM in OFDM-Ro-FSO transmission system

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ABSTRACT

Radio-over-free-space-optics (Ro-FSO) technology may pave the way towards a ubiquitous platform for seamless integration of radio and optical networks without expensive optical fiber cabling. In this paper, to increase the capacity of Ro-FSO, mode division multiplexing (MDM) of two modes has been capitalized in a three-channel WDM system spaced by 1 nm over a FSO link of 80 km, resulting in a 120 Gbps six-channel Ro-FSO system. The SNR and received power of MDM of two Laguerre-Gaussian modes LG00 and LG01 is compared with respect to MDM of two transverse donut modes. The performance of four-level quadrature amplitude modulation (QAM) for orthogonal frequency division multiplexing (OFDM) of radio subcarriers in the WDM-MDMs system is investigated for mitigation of frequency-selective fading under strong atmospheric turbulence.

1. Introduction

The last decade has experienced an enormous growth in the development of optical transmission systems in almost all parts of the world. The increasing demand for bandwidth due to proliferation of video and multifarious online services has inspired the generation of new optical techniques to accommodate the rise in number of subscribers. The International Telecommunication Union (ITU) has reported 7.5 billion cellular subscribers in 2015 [1]. Due to the explosive growth of mobile subscribers and data surge, it is increasingly a challenge for the ITU to allocate limited radio frequency (RF) spectrum among various wireless operators. Ro-FSO is a prospective technology for addressing the growth of mobile subscribers, enabling transmission of multiple RF signals via a high-speed optical carrier without expensive optical fiber cabling or licensing for RF solutions. In Ro-FSO, utilizing an optical carrier exploits a different segment of the electromagnetic spectrum for the mobile backbone, thus alleviating RF spectrum congestion issues in current wireless networks. Ro-FSO harnesses the merits of both radio-over-fiber (RoF) and free-space optical (FSO) technologies [2]. As with RoF, Ro-FSO allows expensive equipment responsible for processes such as RF up-down conversion, handoff, switching, coding and multiplexing to be centralized and shared among all base stations [3]. In addition, the ability of RoF technology to distribute the RF signals at large bandwidth, low attenuation losses and low power consumptions are some of the main benefits of RoF technology shared by Ro-FSO. These features assure compatibility with existing mobile cellular architectures. On the other hand, in contrast to RoF, free-space optics (FSO) allows the transportation of data signals through the atmosphere instead of optical fiber, thus eliminating the need for exorbitant optical fiber installations and allowing for rapid adoption [4–7]. Hence, Ro-FSO is fascinating as an enabling ubiquitous platform for seamless integration with RF wireless networks to extend the achievable capacity of current wireless networks rapidly and cost effectively [8–11]. Significant research in Ro-FSO has focused on experimental measurements [12–14] and statistical modeling [15,16] under various atmospheric turbulence and scintillation effects in Ro-FSO systems. Most of these Ro-FSO systems adopt wavelength division multiplexing (WDM) for increasing the channel capacity [17,18]. Apart from wavelength, the Eigen mode is an un-capitalized dimension which may be valuable for increasing the capacity in Ro-FSO transmission systems. Eigen modes are used in mode division multiplexing (MDM) to drive the propagation of a number of channels on different modes generated by various mechanisms such as spatial light modulators [19–21] and optical signal processing [22–24]. While Ro-FSO offers several advantages, atmospheric turbulences such as rain, fog, haze, snow, and scintillations are major channel degradations against which Ro-FSO systems need to safeguard in order to improve the signal to noise ratio in Ro-FSO networks. [25–27]. Although MDM-WDM is widely investigated by the researchers [28–32] in optical communication networks but it still unexploited area in Ro-FSO systems.

Orthogonal frequency division multiplexing (OFDM) is an established technique in wireless communications for alleviating frequency-selective fading and narrow-band interference, having been approved for several digital communication standards including IEEE 802.11

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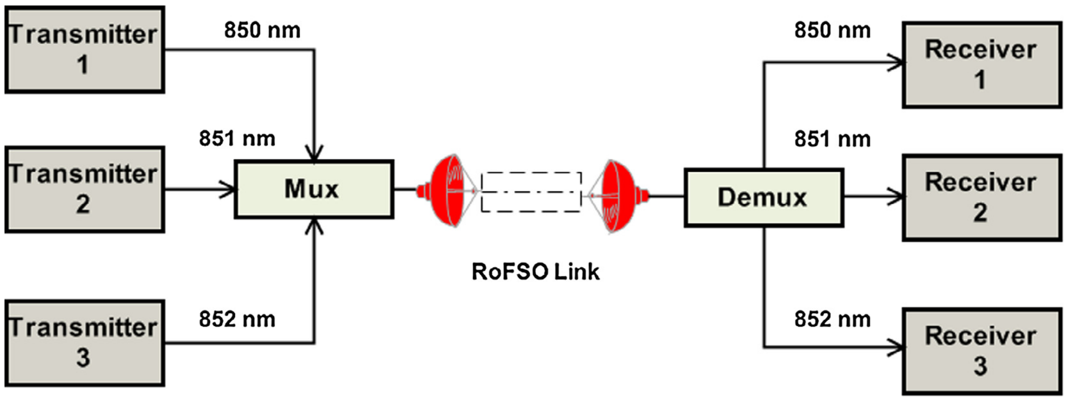

Fig. 1a. Proposed MDM-WDM Ro-FSO Transmission System.

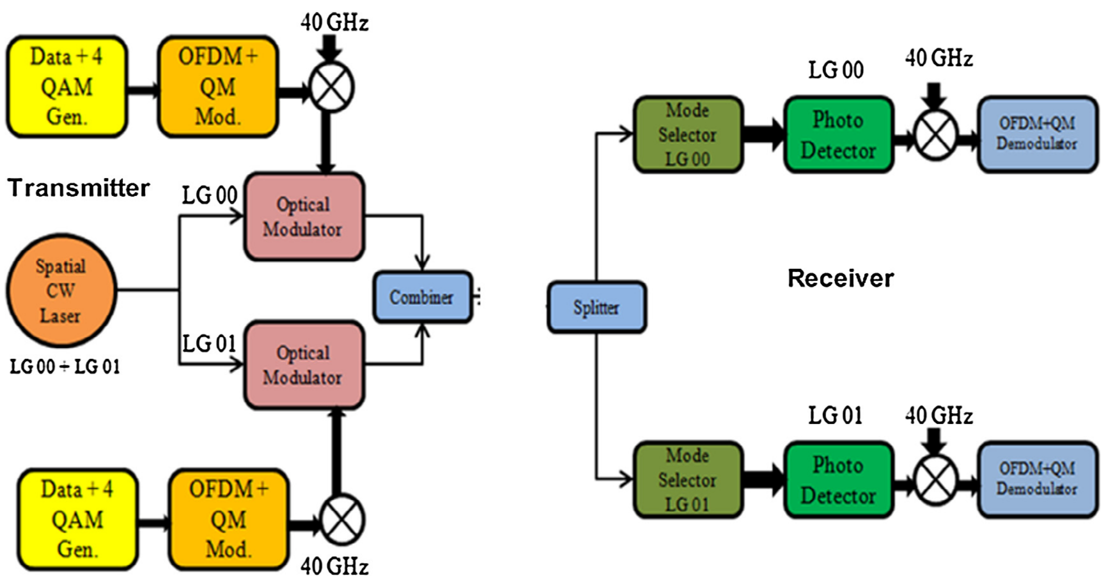

Fig. 1b. Sub-Channel of proposed Ro-FSO Transmission System.

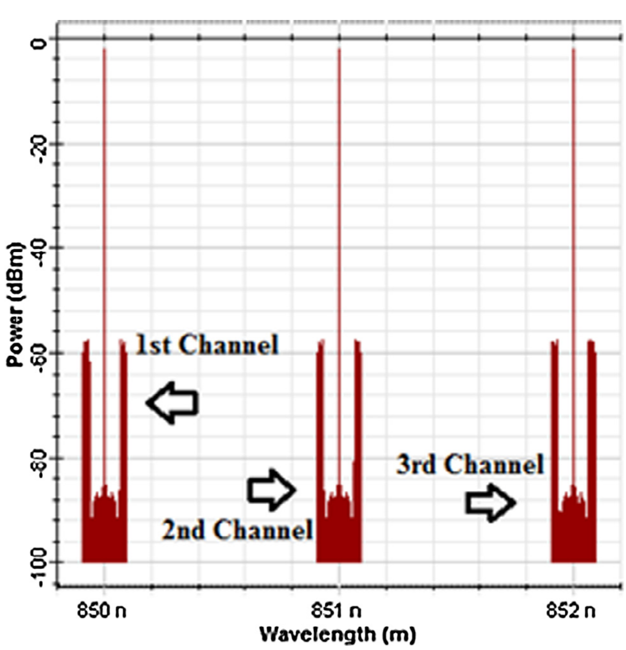

Fig. 2. Measured optical spectrum at transmitter.

local area network and IEEE802.16 wireless broadband [33–40]. We envisage that OFDM may be adopted in a MDM-WDM Ro-FSO system for mitigating frequency-selective fading. In this paper, we demonstrate four-level quadrature amplitude modulation (QAM) efficient spectral modulation of 512 OFDM radio subcarriers for frequency-selective mitigation before WDM and MDM in the optical domain. The main contribution of this work is to design 6 × 20 Gbps − 40 GHz high speed Ro-FSO communication system by incorporating MDM of LG and Donut modes with WDM scheme. Furthermore, the performance of LG and Donut modes is also evaluated over Ro-FSO link. The remainder of the paper is organized as follow: Section 2 elucidates the main principles of the MDM-WDM-OFDM model and simulation parameters. Section 3 describes the results and discussions, followed by the conclusion in Section 4.

2. System description

A schematic diagram of the proposed Ro-FSO WDM architecture is shown in Fig. 1a. In the proposed architecture, three WDM channels with a channel spacing of 1 nm are transmitted. Two Laguerre-Gaussian (LG) modes are generated by using continuous wave (CW) spatial laser whereas DT modes are generated by using donut mode generator as shown in Fig. 3. Each channel consists of again two sub-channels in which two independent 40 GHz radio signals are modulated at 20 Gbps