Selective Mode Excitation in SCM-OCDMA

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Abstract — A six-channel 2.4GHz subcarrier multiplexing - optical code division multiple access (SCM-OCDMA) system in conjunction with the selective excitation of LP01 and LP02 modes is presented for a multimode fiber Local Area Network. Simulation results demonstrate that mode selectivity increases the bandwidth-distance product and improves the BER performance of the channel.

Keywords—spectral amplitude coding optical code division multiple access, SAC-OCDMA, multimode fiber, subcarrier multiplexing (SCM), selective mode excitation

I. INTRODUCTION

The surge of triple play services and rise of cloud computing trends are encumbering multimode fiber backbones in Local Area Networks (LANs). To surmount the current bandwidth limit of a multimode fiber backbones in LANs, it is imperative to curtail modal dispersion, the main source of signal degradation in multimode fiber [1]. Selective mode excitation has been shown to improve the impulse response and mitigate modal dispersion in multimode fiber. Successful approaches for selective mode excitation include contriving holographic wavefronts [2-5], modal decomposition methods [6, 7], radial offsets [8-10], employing a photonic crystal fiber [11] and gratings [12, 13]. These techniques confine modes with similar propagation constants to a specific channel and give rise to multiple-access through the inherent modes of a multimode fiber.

Another multiple-access technique which recently garnered significant interest is optical code-division multiple-access (OCDMA). In OCDMA, each user transmits on different codes using filters. The code diversity allows the realization of a routed optical network with very low blocking probability, high privacy and low signal-attenuation[14].

Spectral-amplitude coding (SAC) is a variant of OCDMA, recognized for its ability to constrain MAI using broadband sources such as light-emitting diodes (LEDs)[15].

The advancement of both optical multiple-access techniques is flanked by the surge of radio connectivity through mobile devices in Local Area Networks. Subcarrier multiplexing (SCM) complements optical multiple-access techniques by enabling the modulation of the baseband data on a radio subcarrier before being modulated on an optical carrier [16]. Hence, each signal occupies a distinct portion of the optical spectrum surrounding the centre frequency of the optical carrier. At the receiving side, the receiver is tuned to the only corresponding subcarrier frequency, filtering out irrelevant subcarriers. Multiplexing and demultiplexing of the subcarriers are carried out in the electrical domain.

The objective of this paper is to introduce for the first time selective mode excitation by laser diodes for SCM-OCDMA. LEDs used in SAC-OCDMA are incoherent and thermal in nature, thus the system suffers from phase-induced intensity noise (PIIN) [17]. On the other hand, the laser diode is coherent, maintains a high power level over long distances, has a long lifetime and low operating cost. In addition, distinct modes may be emitted and the frequency range is sufficient for the allocation of several OCDMA channels.

In this paper, we demonstrate that selective mode excitation in conjunction SCM-based SAC-OCDMA to increase the bandwidth-distance product of the multimode fiber channel. The paper proceeds as follows. Section II describes the simulations for the proposed system and Section III analyzes the simulation results. The paper is concluded in Section IV.

II. SIMULATIONS

The six-channel SCM-OCDMA system in conjunction with selective mode excitation is shown in Fig. 1, simulated in Optsim [22]. The system supports triple-play service for two users through a 1.5km multimode fiber. A 1550nm laser diode is used for selective excitation of linearly polarized modes as LEDs are only capable of generating a Guassian wavefront. The laser diode emits at 1550nm and has a spectral width of 0.8nm. Data streams delivering different services are modulated onto a radio subcarrier, then optically modulated at a bit rate of 2.4GHz to unique wavelengths based on a multi-diagonal (MD) codeword [18]. Bit-shifting according to the position of 1's in the codeword is used for precise separation of the serial transmission. The transmission of triple-play services for the first user is multiplexed onto mode LP01 of a laser diode whereas the triple-play delivery for the second user is multiplexed on the LP02 mode. The transmitted power is -10dBm The data rate of each user is 2.4GHz. An optical multiplexer is used for combining the modulated code sequences for transmission on a single multimode fiber. At the receiver, the signal is retrieved by optical filters corresponding to the MD

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codeword, then bit-shifted according to the position of 1's in the codeword. A spatial photodiode is used to couple the received power from modes LP01 and LP02 for the first user and second user respectively.

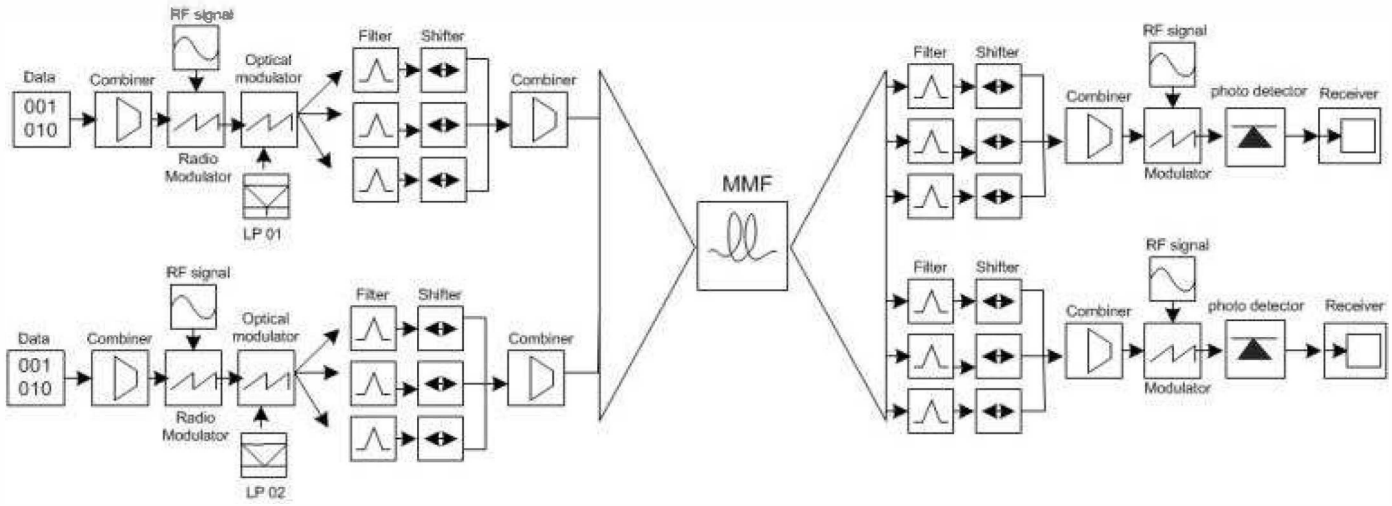

Fig 1. Selective mode excitation in SCM-OCDMA system for delivery of triple-play services for two users through six channels

III. RESULTS AND ANALYSIS

Fig 2 and Fig. 3 show the eye diagrams after the signal is propagated through the 1.5 km MMF without bit-shifting and with bit-shifting respectively. It is apparent that bit-shifting reduces dispersion significantly. A Q-factor of 25.5 and bit-error rate (BER) of the order of 10-100 are achieved, as shown in Fig. 4.

The tradeoff between distance and data rate manifests in SCM-based SAC-OCDMA systems due to modal dispersion in multimode fiber. The simulation results demonstrate that the bandwidth-distance product has improved by increasing the transmission distance in [20] and increasing the data rate attained in [21]. This suggests that the orthogonality of LP modes [22] reduces the interference between the SCM-OCDMA channels.

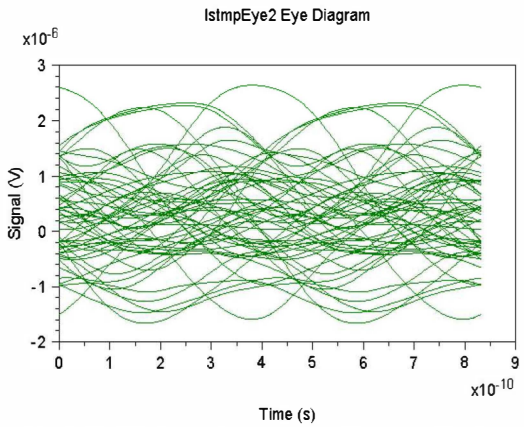

Fig. 2: BER Tester Decision Eye for the users without shifting

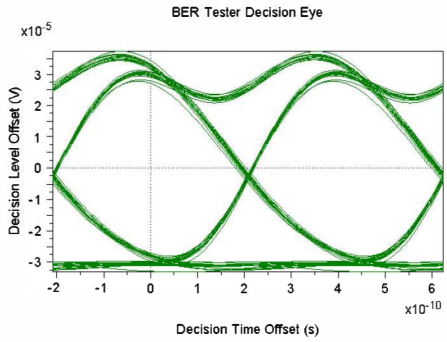

Fig. 3. Eye diagram with bit-shifting

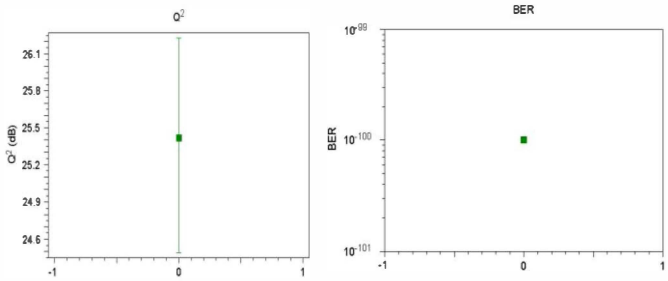

Fig. 4. Q factor and BER performance with bit-shifting

IV. CONCLUSION

Simulations of a subcarrier multiplexing-optical code-division multiple-access (SCM-OCDMA) system in conjunction with selective mode excitation of LP01 and LP02 modes have demonstrated the successful delivery of triple-play data at 2.4GHz for two users on six channels. The LP modes were selectively excited using laser diodes and detected using spatial photodiodes. Future work will be undertaken to investigate the capacity of users and channels that may be accommodated.

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