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OFDM MMF Optical Communication Transmission System Based on Mode Group Division Multiplexing

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To increase the transmission capacity of multimode fiber (MMF) drastically, Mode Group Division Multiplexing (MGDM), an optical MIMO technique, can be applied. With MGDM, different mode groups, propagating in MMF are used to carry different information. In this paper, Orthogonal Frequency Division Multiplexing (OFDM), a multi-carrier modulation scheme which not only can make efficient use of the available spectrum but is more resistant to frequency selective fading is proposed in an MGDM system. Simulation results of a 2 × 2 OFDM MGDM system operating at high bitrates will be presented and discussed and an improved performance is shown.

Introduction

Mode Group Diversion Multiplexing (MGDM), an optical MIMO technique, has been proved as an efficient scheme to overcome the limited bandwidth of the multimode fiber (MMF) [1,2]. In MGDM, different mode groups of the light, propagating in a MMF are used to carry different information, so that the data throughput is increased without having additional bandwidth. It is similar to make multipath propagation, generally a pitfall in wireless transmission to a benefit for the user. In this paper, Orthogonal Frequency Division Multiplexing (OFDM), a multi-carrier modulation scheme which not only can make efficient use of the spectrum but is more resistant to frequency selective fading is investigated in an optical MGDM system.

Frequency Selective Fading

Frequency selective fading is a type of signal fading in the multipath environment. The propagation route of each mode in MMF could be seen as an independent path. Due to the different propagation distances, the arrival times for different modes will be different. The superposition of all excited modes with time delays will cause deep transfer dips in some frequencies, which is called as frequency selective fading. In reference [3], the frequency response of the MMF was regarded as a combination of delta functions corresponding to different delays of different guided modes. The frequency response of the MMF with N guided mode groups can be written as:

$$H_{Fiber}(f) = \sum_{n=1}^{N} e^{-j2\pi f t_{s,n}}$$

where the time delay of each mode $t_{s,n}$ is defined as uniformly distributed.

Fig. 1 gives the measured normalized frequency response of a 1km long 100/140µm core/cladding diameter graded

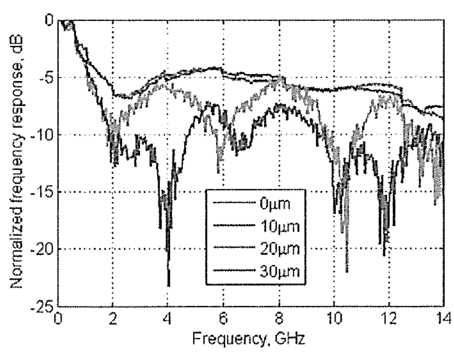


Fig. 1. Normalized frequency response with different radial offset launching.

index (GI)-MMF with selective launching [4]. A standard single mode fiber (SMF) with a core diameter of 9μm is utilized to excite modes at the input facet of GI-MMF. At the receiving side, a same SMF is used to couple the output light of a mode or mode group at the maximum power point. It can be seen that the frequency selective fading is less serious when the radial offset of launching is smaller. This can be explained by the decreased number of modes when the offset launching is smaller. Therefore, when there exist only one or a few modes in the MMF, the MMF could be regarded as a SMF, which has a frequency flat fading instead of frequency selective fading.

Mode Group Division Diversity (MGDM)

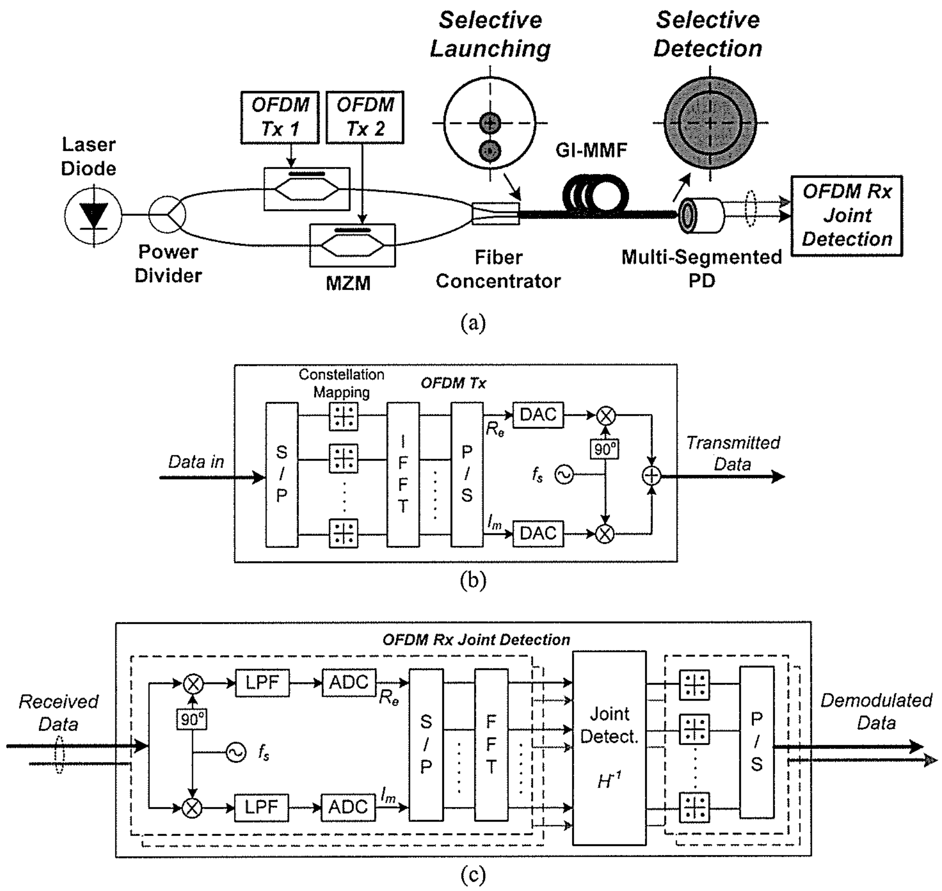
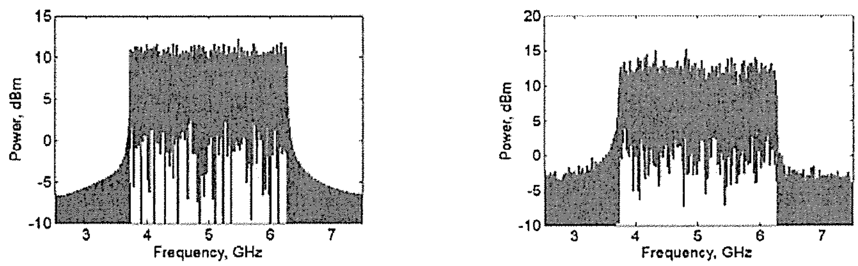


Fig. 2. (a) Proposed 2 × 2 optical OFDM MGDM system. Schematic representation of (b) OFDM transmitter and (c) OFDM receiver with joint detection. Mach-Zehnder modulator (MZM). Serial-to-parallel (S/P), Parallel-to-serial (S/P) and Joint detection (Joint Detect.).

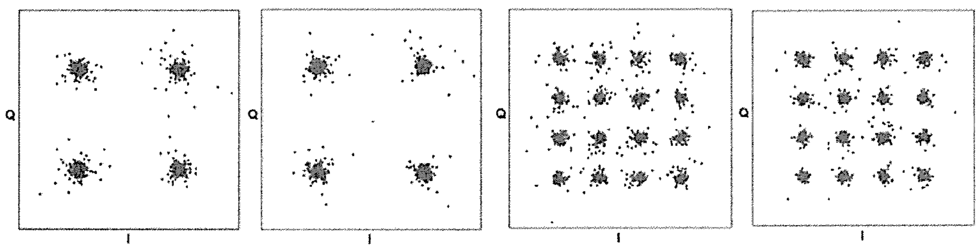
Two different subchannels using two different mode groups are used by launching and detecting with different radial offsets. Fig. 2 (a) depicts the proposed 2 × 2 optical OFDM system based on MGDM. The schematic representation of the OFDM transmitter and the OFDM receiver with joint detection are given in Fig. 2 (b) and (c). The selective launching [5] is realized by launching two light beams into the MMF's core with and without a radial offset from the radial axis. These two parallel light beams are coming from a fiber concentrator with a small distance of 30μm between the two output waveguides. At the output facet of the MMF, a multi-segmented photo-detector (PD) is utilized to detect the high order mode groups and low order mode groups separately. As discussed in the former part, the frequency selective fading of MMF links is induced by the different delays of all guided mode groups. Due to the application of the selective launching in MGDM, each subchannel in MMF link excites only one or a few mode groups so that the frequency selective fading is not as serious as in the overfilled launching case. Besides, MMF applications are mainly in short distance transmission, therefore the differences in mode delays becomes negligibly small. However, it should be pointed out that even in the frequency selective fading case, the proposed optical OFDM MGDM scheme is also feasible because of the insensitive characteristic of OFDM to the frequency selective fading. With the aid of an adaptive bit loading algorithm, the bit error rate can be reduced effectively through disuse of subcarriers in deep nulls, as proposed in [6].

Simulations



(a) (b)

Fig. 3. Spectrum of transmitted OFDM symbol (a) before and (b) after transmission over the MMF.



(a) (b)

Fig. 4. Constellation of the demodualted OFDM symbol in (a) 4QAM and (b) 16QAM.

The bit error rate performance of the 2 × 2 OFDM system is determined by means of simulations. Data in, in Fig. 2(b)) is the serial input stream for each OFDM transmitter (Tx). After Serial-to-parallel conversion, bit rate of parallel baseband streams is 10Mbit/s which are mapped to complex quadrature amplitude modulation (QAM) signals. The baseband QAM OFDM signal is generated with a 512 points inverse-fast-Fourier transform (IFFT). 256 subcarriers are utilized to carry the signals. Other subcarriers could be used for pilots or other functions in practice. Then the baseband QAM OFDM signal is up-converted to 5GHz. A 2 × 2 transfer matrix H is used to simulate the MMF subchannels including crosstalk. Fig. 3(a) and (b) give the spectra of transmitted OFDM symbols in one subchannel before and after transmission over the MMF link, respectively. In practice, the transfer matrix of the MMF links can be determined by sending a training sequence before the transmission of data symbols. Fig. 4(a) and (b) show an example of the constellation of the demodulated OFDM symbol using 4QAM (total data rate is 10Gbit/s for 2 channels) and 16QAM (20Gbit/s), respectively. Fig. 5 depicts an example of the symbol error rate versus signal-noise-ratio (SNR) in case using BPSK, 4QAM and 16QAM modulation. It can be seen that our proposed 2 × 2 optical OFDM system has a good performance and could increase the capacity of MMF without having additional bandwidth.

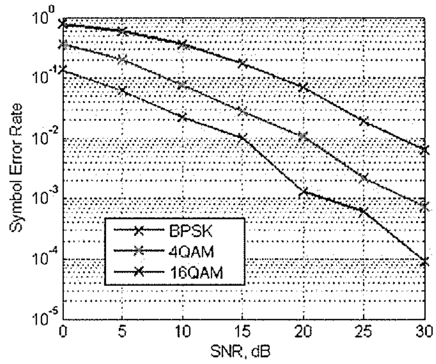


Fig. 5. Symbol error rate versus SNR (dB) in different modulation levels

Conclusion

Frequency selective fading in a 1km MMF has been measured in the case of selective launching. The positive effect of the MGDM technique to minimize the frequency selective fading was analyzed. The performance of a 2 × 2 optical OFDM system based on MGDM was investigated through using simulations. The symbol error rate results shows an increased performance.

Acknowledgement

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