Photonic Envelope Detector for Broadband Wireless Signals using a Single Mach-Zehnder Modulator and a Fibre Bragg Grating

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Abstract

A novel technique for envelope detection of wireless signals using a single Mach-Zehnder modulator is presented. Experimental demonstration of 1.25 Gbit/s ASK modulated 35 GHz carrier envelope detection is presented.

Introduction

The increased demand in wireless transmission of broadband data has pushed research efforts towards the generation and detection of wireless signals at millimetre wave frequencies with data rates of some Gbit/s, using traditional photonic mixing arrangements [1, 2]. Application of such wireless Gb/s capable radio over fibre (RoF) systems may be for instance wireless extension and bridging of FTTH networks.

Recently, the generation of more spectrally efficient modulation formats like MQAM at 40/60 GHz band have been reported [3,4]. When operation at higher frequency bands such as 94 GHz or 120 GHz is achieved, simpler bandwidth inefficient modulation formats like amplitude shift keying (ASK) can be used, due to the huge available bandwidth. To demodulate an ASK modulated carrier, envelope detection is needed. Recently envelope detection schemes have been proposed like for demodulating 10 Gbit/s ASK modulated 120 GHz carrier [1] using an electrical envelope detector and later performing the E/O conversion, or using an electro-absorption modulator (EAM) biased at its inflection point and external optical injection of a DFB laser [5], both of which involve complicated electronics and optical devices. In this paper a simplified photonic envelope detector with a single Mach-Zehnder modulator and a fibre Bragg grating is proposed. The photonic envelope detector converts an ASK modulated wireless carrier into an ASK modulated optical carrier for feeding into an optical network. Experimental demonstration of envelope detection of 1.25 Gbit/s ASK modulated 35 GHz carrier is presented, and an error free detection obtained. The choice of 1.25 Gbit/s, and 35 GHz of carrier were determined and limited by the electrical mixer and amplifiers, and not the actual principle of operation.

Working Principle

A photonic envelope detector should be able to convert the amplitude modulated RF signals to optical ASK signals. In the proposed photonic envelope detector, the output of a CW light source is modulated with the amplitude modulated RF carrier using a Mach-Zehnder modulator biased at its minimum transmission point. The output of the MZM is an optical carrier with the electrical signal half wave rectified, modulated on it as shown in Fig. 1.

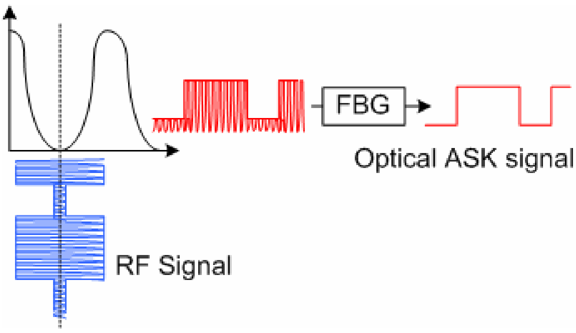

Figure 1: Principle of photonic envelope detection

The output of the MZM contains two sidebands separated by f_{LO}, with the baseband data ASK modulated on each of them. Later, the output of the modulator is passed through a fibre Bragg grating, and only one sideband is selected. It should be noted that the bandwidth of the FBG should be more than twice the RF data rate. The optical carrier output of the FBG contains the data amplitude modulated on it.

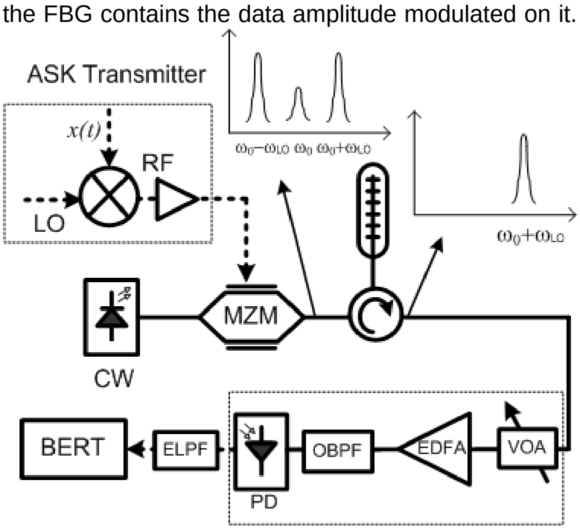

Figure 2: Schematic of the photonic envelope detector experimental setup.

Experimental Setup

Fig. 2 shows the schematic of the experimental setup used for the photonic envelope detector. It consists of

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three blocks: the electrical ASK modulated carrier generation, the optical envelope detector, and the optical pre-amplified receiver for measuring the bit error rate. The electrical signal was generated by mixing a 1.25 Gbit/s 2^{31}-1 PRBS data, *x(t),* with a 35 GHz LO carrier. The output of the mixer was amplified to +13 dBm using an electrical amplifier prior to modulating the optical carrier. In the envelope detector, a continuous wave laser source at 1549.68 nm with an output power of +11 dBm was externally modulated by the 1.25 Gbit/s ASK 35 GHz carrier using a 50 GHz bandwidth MZM, biased at its minimum transmission point.

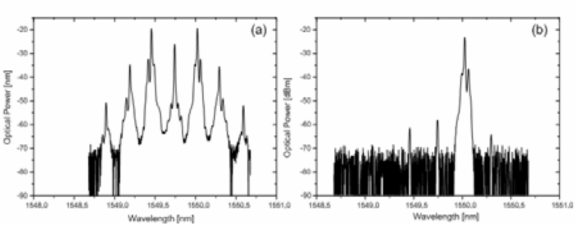

Figure 3: The optical spectrum at the output of the Mach-Zender modulator (a), at the output of the fibre Bragg grating (b).

The optical spectrum of the MZM output is shown in Fig. 3(a). A fibre Bragg grating was used with a circulator for filtering out the desired optical sideband. A 25 GHz bandwidth FBG centred at 1550 nm was used for filtering the upper sideband. The output of the filter is a baseband data ASK modulated optical carrier at 1550 nm. The optical spectrum of the ASK signal is shown in Fig. 3(b).

To measure the bit error ratio curve of the optical ASK signal a typical preamplified receiver was used. The output of the FBG was passed through an erbium doped fibre amplifier (EDFA) and followed by a tuneable band pass filter centred at 1550 nm with a bandwidth of 1 nm for filtering the accumulated stimulated emission (ASE) noise of the EDFA. A 12.5 Gbit/s photodiode was used to convert the optical signal to the electrical domain. A 900 MHz low pass filter was used to filter the received data prior to bit error ratio test.

Results

Fig. 4 shows the BER curve plotted against the average optical power received to the pre-amplified receiver. Error free detection was obtained with received power as low as -22 dBm. For a BER of 10^{-9}, a received optical power of -23.7 dBm was required. One of the challenges faced was the high Vπ of the MZM and not so high output power of the electrical amplifier. As an example to drive the MZM with full cycle a 24 dBm RF signal is required, and the amplifiers available in the lab can only generate +13 dBm of power. The receiver sensitivity can be fairly improved by using a high power amplifier.

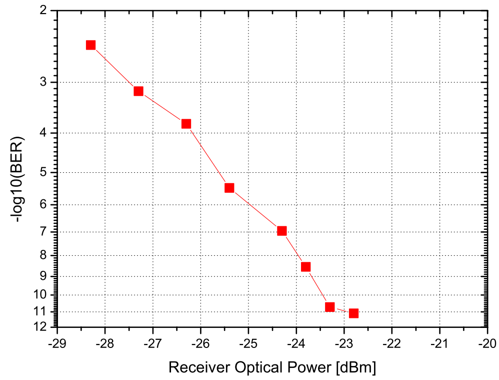

Figure 4: Measured bit error ratio plotted against the average received optical power.

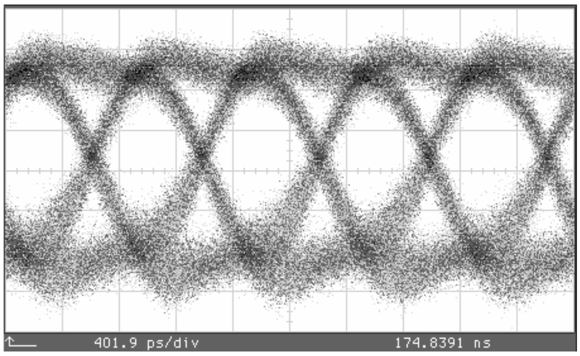

Figure 5: The electrical eye diagram at a receiver power of -24 dBm.

Conclusions

A simplified novel photonic envelope detector for converting wireless signals into optical baseband ASK modulation based on a single Mach-Zehnder modulator and a fibre Bragg grating is presented. Envelope detection of 1.25 Gbit/s ASK modulated 35 GHz carrier was experimentally demonstrated, and a error free detection achieved.

Acknowledgements

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