Radio Frequency Transparent Demodulation for Broadband Wireless Links

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Abstract: Novel demodulation technique for radio over fiber systems, transparent to RF carrier frequency, employing coherent detection and baseband digital signal processing is presented for the first time. Multi-gigabit signal demodulation at 40GHz RF is demonstrated

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1. Introduction

The increase in the data capacity demand is pushing the development of multi-gigabit wireless systems. Currently, there is a lot of research effort underway in order to develop multi-gigabit wireless systems addressing applications like LAN bridging, inter-building communications, mobile backhaul, etc [1-3]. Several frequency bands in the millimeter wave frequency regime (60 GHz, 70/80 GHz, >100 GHz etc) have a few GHz of available bandwidth, which could potentially enable gigabit wireless transmissions. However, in order to achieve multi-gigabit capacity in the limited available millimeter wave bandwidth, spectrally efficient modulation formats like QPSK and M-QAM are required. Radio over fiber technologies [4] provide a good solution for such broadband wireless systems and up to 10 Gb/s wireless signal generation with both, on-off-keying and spectral efficient M-QAM modulation has been demonstrated [2,3]. However, the detection of these vector modulated multi-gigabit signals using conventional electrical methods becomes complicated when the bit rate increases and carrier frequency approaches millimeter wave frequencies. Recently, many photonic techniques for demodulation of M-QAM signals have been proposed [5, 6], but still require relatively complex high-bandwidth analog phase locked loop. Also, recently novel digital coherent receiver structures have been proposed for radio over fiber links [7,8]. Although, the demonstrated digital coherent techniques do not require electronic or optical phase locked loops, they still require electronics such as A/D converters or signal sources at high RF carrier frequencies [9].

In this paper, we present a novel technique for demodulation of high-frequency multi-gigabit RF signals using coherent detection and baseband digital signal processing. The advantage of the proposed technique is that it is transparent to RF carrier frequency and only requires A/D converters at the baseband/data rate frequency. In order to demonstrate the RF frequency transparency, demodulation of 2.5 Gb/s QPSK modulated data signal, at 40 GHz and 35 GHz RF carrier frequency, is experimentally demonstrated.

2. Experimental set-up

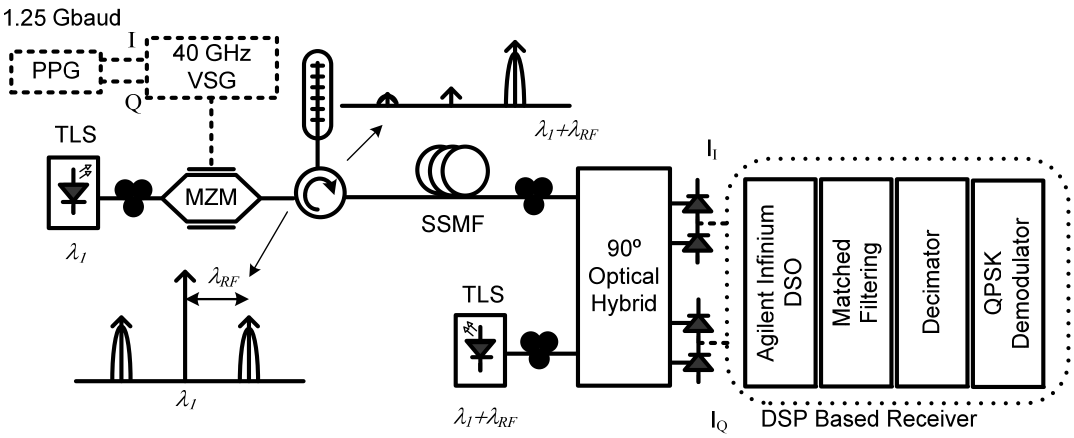
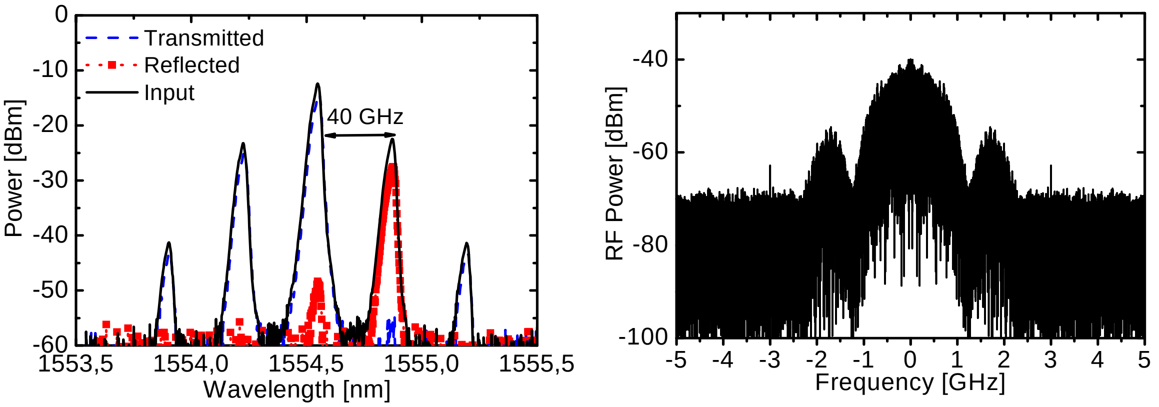


Figure 1: Schematic of the experimental setup of RF transparent demodulator.

The schematic of the experimental setup is shown in Fig. 1. A pattern generator is used to generate inphase and quadrature components of the 1.25 Gbaud QPSK data signal Thereafter, a vector signal generator is used to up-convert the generated 2.5 Gb/s QPSK signals at the RF carrier frequency of 40 GHz. The electrical power of the RF signal was set to +12 dBm. An optical carrier at the wavelength of 1554.68 nm generated from an external cavity tunable laser (TLS) was amplitude modulated, with the 1.25 Gbaud QPSK modulated 40 GHz RF carrier frequency data signal, using a MZ modulator biased at the quadrature bias point. The output of the MZ modulator consists of the optical carrier (1554.68 nm), and two sidebands, at 1554.36 nm and 1555.0 nm, each modulated with 1.25 Gbaud QPSK data and separated by 40 GHz/0.32nm. The main idea behind our approach is now to filter out one of the sidebands of the modulated optical carrier and in this way only transmit baseband data making this scheme RF carrier frequency independent, and also dispersion tolerant since only the baseband data is transmitted. This is illustrated in Fig. 1. To filter out the sideband at 1555.0 nm, a fiber Bragg grating (FBG) centered at 1555.0 nm with an optical bandwidth of 25 GHz is used in combination with an optical circulator. The optical signal at 1555.0 nm contains purely 1.25 Gbaud QPSK data signal modulation. The optical data signal at 1555.0nm, carrying 2.5 Gb/s of data, is then transmitted over a 26 km prior to coherent detection, which only requires baseband signal processing at twice the data rate. An LO optical signal at around 1555 nm with a linewidth of around 100 kHz generated from another tunable external cavity laser is mixed with the filtered sideband in the optical 90° hybrid. The inphase I_i and quadrature I_q optical components are detected using a pair of balanced photoreceiver, which were inbuilt in the optical 90° optical hybrid. The photodetected signals were then digitized using a high bandwidth realtime oscilloscope with 13 GHz analog bandwidth and the sampling rate up to 40 GS/s. The digitized photodetected signals were later used for offline digital signal processing consisting of matched filtering, decimation and QPSK demodulation module [8].

4. Results

In Fig. 2(a), optical spectra of the input, transmitted and the reflected signal from the FBG is shown. It is the reflected signal at 1550.0nm containing 2.5 Gb/s QPSK data modulation that is sent to the transmission span of 26 km and subsequent signal demodulation. It is observed that the FBG suppresses the optical carrier and sidebands by more that 30 dB, allowing for pure baseband transmission.

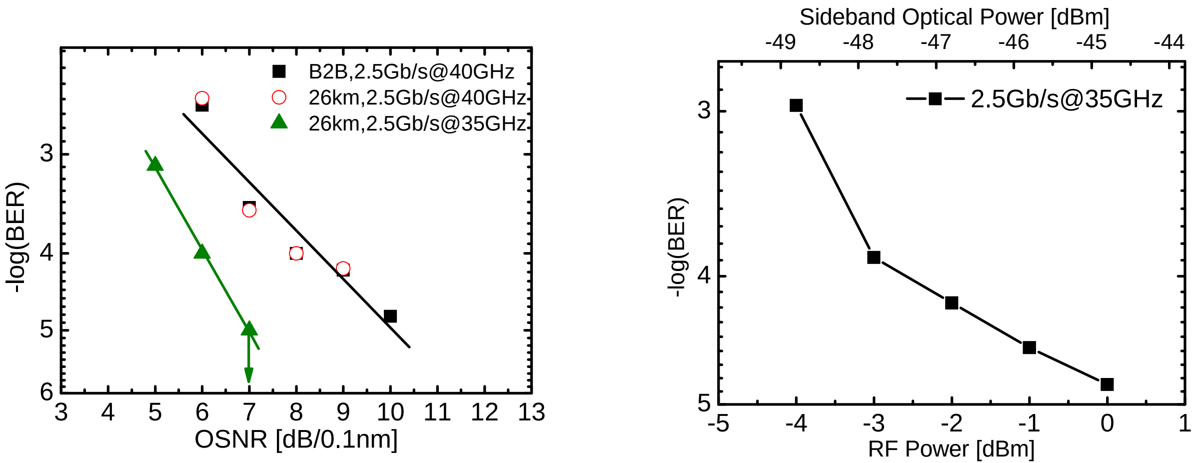


(a) (b)

Fig. 2 (a) Optical spectrum input to, reflected from and transmitted through the fiber Bragg grating (a), the electrical spectrum of the photocurrent output from one of the arms of the 90° optical hybrid.

In Fig. 2(b), the frequency spectrum of the detected photocurrent (one of the outputs of the 90° optical hybrid) is shown. It is observed that the signal is in baseband with a small frequency offset from zero due to frequency mismatch between the transmitter and LO laser. This frequency offset is corrected by the digital signal processing based demodulation algorithm [8]. Fig. 3(a) shows the Bit Error Ratio (BER) curves plotted as a function of the Optical Signal to Noise Ratio (OSNR). To begin with, we focus on the data signal at 40 GHz RF carrier frequency. First, the BER was measured in a back-to-back scenario, and then a 26 km fiber transmission was performed. Fig. 3(a) shows that for the back-to-back scenario successful signal demodulation is achieved with the receiver sensitivity of 8 dB in order to obtain the BER of 10^{-4}. Additionally, it can be observed from Fig. 3(a), that the 26 km of fiber transmission did not induce any penalty for the demodulation of a 2.5 Gb/s QPSK signal at 40 GHz RF carrier, proving the dispersion tolerance of the proposed scheme.

Later, the RF carrier frequency was changed to 35 GHz while still keeping the 1.25 Gbaud QPSK data signal modulation. Changing the RF carrier frequency from 40 GHz to 35 GHz, has moved the sideband center wavelength, so in order to be able to filter the sideband properly, the transmitter laser was detuned to maximize the filtered optical power. In Fig. 3(a), the BER as a function of OSNR is also plotted when the RF carrier frequency is 35 GHz. The error free (zero errors counted) signal demodulation is achieved when the OSNR is 7 dB, which is indicated by an arrow in Fig. 3(a). An improvement in the BER is observed compared to the case when the RF carrier frequency was 40 GHz, which is due to the increased frequency response of the MZ modulator at 35 GHz compared to 40 GHz. Also a 2 dB of increase in the sideband power was recorded.



(a) (b)

pFig. 2 The bit error ratio plotted as a function of OSNR (a), and as a function of the electrical RF power input to the MZ modulator.

To analyze the effect of the received RF power, the BER was measured as a function of the RF signal power without any additional optical noise and plotted in Fig. 3(b), for the RF carrier frequency of 35 GHz The RF signal power was varied from -4 dBm to 0 dBm, and the corresponding optical sideband power was also measured and is shown in Fig. 3(b). The Fig. 3(b) shows that even for very low RF signal power of -4 dBm, (sideband optical power of -48 dBm), BER of app. 10^{-3}, is achievable. This proves the high sensitivity of the proposed demodulation scheme.

5. Conclusion

A new demodulation technique, transparent to RF carrier frequency based on optical coherent detection and baseband digital signal processing is presented. A successful experimental demodulation of 2.5 Gb/s QPSK data signal at 40 GHz RF carrier frequency is successfully demonstrated. To the best of our knowledge, this is the first RF transparent photonic demodulation technique which is dispersion tolerant and does not use any high-speed electrical RF components.

6. Acknowledgment

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7. References

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