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Published in:
OFC/NFOEC 2008 - 2008 Conference on Optical Fiber Communication/National Fiber Optic Engineers Conference

Link to article, DOI:
10.1109/OFC.2008.4528444

Publication date:
2008

Document Version
Publisher's PDF, also known as Version of record

Local-Oscillator-Free Wireless-Optical-Wireless Data Link at 1.25 Gbit/s over a 40 GHz Carrier Employing Carrier Preservation and Envelope Detection

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Abstract: A local-oscillator-free wireless-optical-wireless system at 1.25 Gb/s over a 40 GHz carrier and 100 km of NZDSF is demonstrated employing optical half-wave rectification, carrier remodulation and envelope detection.

OCIS codes: (060.2360) Fiber optics links and subsystems; (060.5625) Radio frequency photonics

1. Introduction

In recent years, optical fibre based communication systems have shown impressive results with data throughput in the Tb/s region [1,2]. However, the aim of nowadays communication systems is rapidly changing towards tackling the challenging issues regarding interconnection between high-capacity wireless networks and fixed fibre based systems [3].

In this paper, we present a novel, low complexity, bit-rate upgradeable local-oscillator-free interface concept between high-speed wireless and fibre systems, which will allow extending the reach and capacity of already deployed wireless links cost-effectively.

2. System implementation

A plausible application for interfacing broadband wireless and optical fibre systems is presented in Fig. 1.

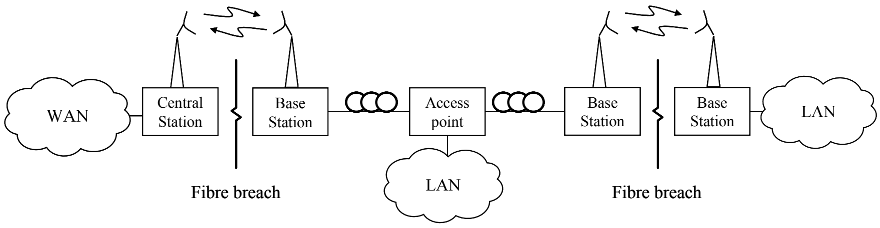

Fig. 1. Emulated wireless-fibre-wireless system

In this example, wireless links are used to interconnect two isolated local area networks (LAN) with a larger wide area network (WAN) bridging two fibre discontinuities, possibly due to permanent topographical conditions and/or cost and time constrains for fibre deployment. In this case, the central station (CS) comprises the needed complex signal processing and radio-frequency (RF) local oscillator, whereas the base stations (BS) will be kept simple requiring solely basic electronic blocks.

3. Wireless to optical conversion with carrier preservation and envelope detection

Traditional wireless systems rely on high-precision local oscillators to up-convert baseband data and down-convert the received signal, and only thereafter requiring low-speed electronics in the succeeding signal processing stages.

In this paper, we demonstrate a photonic wireless to optical signal conversion that enables the extraction of the baseband data without using local oscillators. The principle of operation of our proposed photonic approach is shown schematically in Fig. 2a) and further described in [4]. The modulated radio frequency signal is conveniently applied to the electroabsorption modulator (EAM) to achieve half-wave rectification. Owing to this rectification process, overall system complexity is reduced since the rectified optical signal can be readily detected in a conventional intensity modulation direct detection (IM/DD) receiver. In order to preserve the reference RF carrier, the EAM offers a bandwidth response similar to the carrier frequency. Fig. 2b) depicts the expected functionalities of the access point (AP) subsystem. Since the incoming signal is half-wave rectified and envelope detection is employed, only low-bandwidth photodetection and low-speed electronics are required at this point. The AP should be able to forward data from the WAN to its connected and succeeding LANs. Similarly, it should incorporate data from each LAN into the data link.

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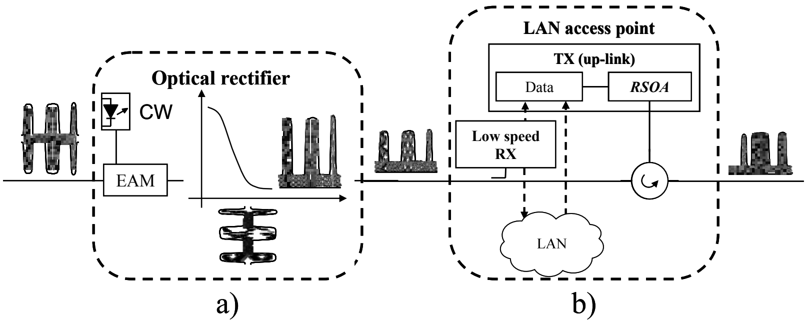

Fig. 2. Optical half-wave rectification and carrier remodulation

This work will not focus on node intelligence features, but will employ a locally generated PRBS signal to test node performance. Data modulation in the AP is realised in a reflective semiconductor optical amplifier (RSOA) in a two stage process. First, the RF carrier is regenerated from the half-wave rectified optical input as RSOA gain is saturated, and low-/high-frequency components are removed/enhanced respectively. Second, the RSOA acts as an intensity modulator owing to electrical gain modulation, where a second PRBS signal is superimposed onto the equalized carrier. These two processes will be dependent on the half-wave rectified signal modulation index and bias voltage driving the RSOA, respectively. Therefore, a compromise is required between these parameters to achieve an adequate and homogeneous performance in a system with multiple access points.

4. Experimental set-up and results

Fig. 3 depicts a simplified schematic of the implemented wireless-optical-wireless transmission system divided into functional building blocks.

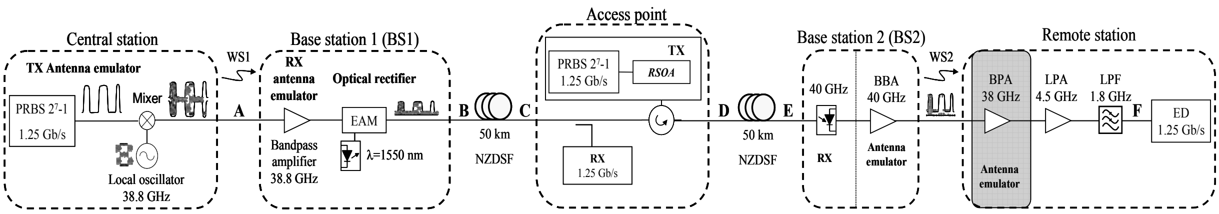

Fig. 3. Schematic setup includes RF signal generation, wireless emulation sections (WS), all-optical half-wave rectification, carrier remodulation and envelope detection. BBA: broadband amplifier; BPA: bandpass amplifier; LPA: low-pass amplifier; LPF: low-pass filter; ED: error detector

The central station generates the wireless-ready signal by mixing a 1.25 Gb/s data signal with a 38.8 GHz local oscillator (A). Data rate is limited by the bandwidth of the available bandpass electrical amplifier in the base station (BS1), but carrier-to-modulation ratio indicates that higher data rates are achievable. This signal is, after the first emulated wireless section (WS1), all-optically half-wave rectified in BS1 (B), and transmitted over 50 km of NZDSF after optical amplification. At the AP (C), the signal is split into two arms. The first one is employed for signal monitoring and for BER measurements. The second arm is injected into a reflective SOA (RSOA) through an optical circulator with enough optical power to saturate the gain of the SOA and generate an equalised carrier. This regenerated 38.8 GHz carrier frequency is then modulated with a second 1.25 Gb/s data signal, and subsequently injected into a second 50 km NZDSF span after optical amplification (D). At the base station (BS2), O/E conversion takes place in a 40 GHz photodetector and subsequent amplification by a 40 GHz broadband electrical amplifier. Due to the large bandwidth of the devices, the high-frequency component of the carrier is preserved and a 38.8 GHz wireless-ready signal is present for transmission over the second emulated wireless section (WS2). This second wireless transmission is simulated by directly connecting BS2 to the remote station (RS), where the bandpass amplifier around the 38.8 GHz carrier was not included since there was no need to reject out of band interference.

Bit pattern and eye diagrams of the signal at different locations within the system are presented in Fig. 4, left. The two upper rows show optical signals, and have been recorded using equipment with bandwidth in excess of 40 GHz. The upper row depicts part of a 2^7-1 PRBS signal modulated at 1.25 Gb/s. The middle row illustrates the evolution of the high-frequency carrier. Electrical signals shown in the bottom row of Fig. 4 (left) have been obtained after bandwidth limitation by a 1.8 GHz 4th order Bessel filter. The same bandwidth limiting configuration has been employed for the BER measurements shown in Fig. 4 (right). Measurements were carried out sequentially without modifying biasing, drive currents or polarisation conditions demonstrating adequate simultaneous performance for each section of the system.

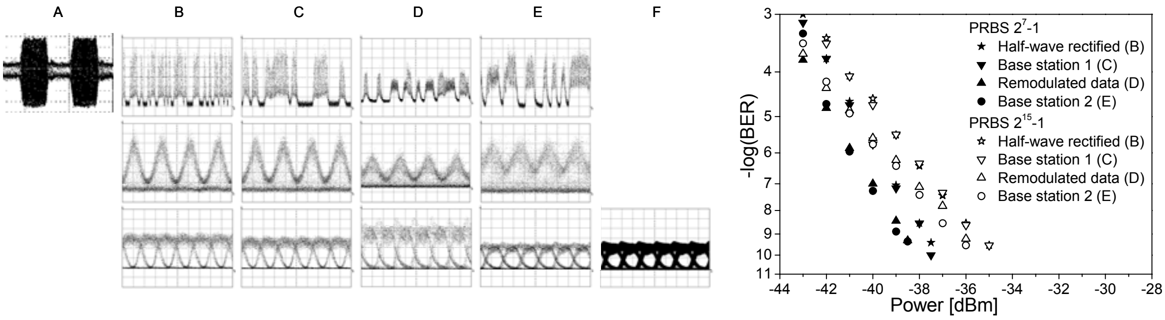

Fig. 4: Bit pattern and eye diagrams along the system (left): Upper row shows data pattern (2 ns/div, except B: 5ns/div). Middle row illustrates carrier eye diagrams (10 ps/div). Bottom row depicts electrical signals (500 ps/div); BER measurements (right) at different locations.

Since one of the key features of the system is the reutilisation of this carrier in WS2, the phase noise characteristics have been investigated. Fig. 5a) shows the single-side band phase noise of the carrier, and Fig. 5b) presents the average measured jitter with integration bandwidth from 10 kHz to 10 MHz. The measured jitter values are moderate, therefore making wireless transmission based on the regenerated carrier feasible in BS2.

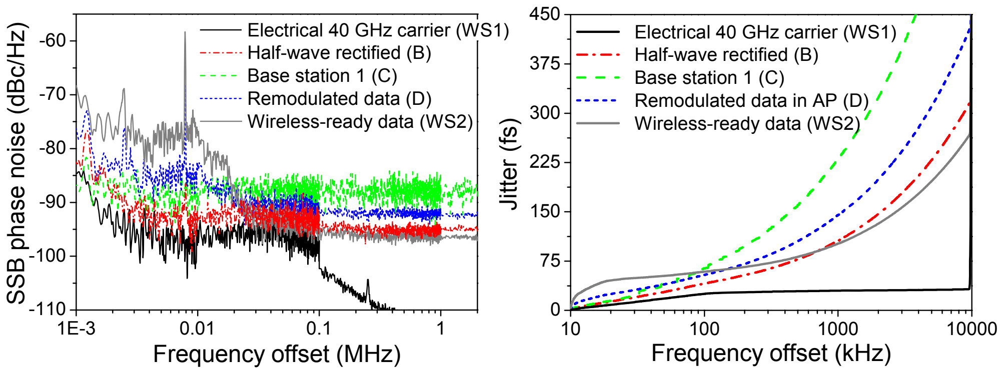

Fig. 5: Phase noise (left) and average accumulated jitter (right) for the 40 GHz carrier

5. Discussion

This paper has focussed on down-link transmission. However, bidirectional links can be implemented on the same principle demonstrated above, possibly over a single or a pair of fibres for the optical link, and employing path diversity and narrow beamwidth antennas for the wireless sections. The proposed system allows upgrading of legacy wireless-fibre links based on conventional local oscillators, and has powerful prospects for new wireless-fibre network deployments due to its flexibility and potential low cost. Moreover, photonic components are common to emerging technologies for broadband access networks such a reflective SOA and reflective SOA-EAM modulator achieving 10 Gb/s operation. Finally, it should be emphasised that even though a 38.8 GHz carrier and 1.25 Gb/s NRZ modulation format have been used in this work due to equipment availability, the method is applicable to other modulation formats and bit-rates.

6. Conclusion

A local-oscillator-free wireless-optical-wireless system at 1.25 Gb/s over a 40 GHz carrier has been demonstrated. The application of optical carrier preservation and baseband reception based on envelope detection, thus requiring only low-bandwidth components in base stations, makes this concept a very strong contender for future meshed wireless networks.

7. References

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