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Hybrid Wired and Wireless System Involving Non-upling Technique

Joseph Zacharias, Celine George, Vijayakumar Narayanan

Abstract: A hybrid Radio over Fiber (RoF) system which is compatible with both wired and 90 GHz wireless transmission is proposed in this paper. Baseband and millimeter wave signals are considered as wired and wireless signal respectively. Hybrid signal consisting of wired and wireless signal is generated using a single Dual Drive Mach-Zehnder Modulator (MZM). Using a 10 GHz local oscillator, non-upling (nine times) increase in signal is achieved. As the system uses low frequency local oscillator and a single modulator, overall cost of the system can be reduced considerably. Results obtained show that the system can transmit both wired and wireless signals over a fiber of length 70 km with acceptable bit error rate (BER).

Index Terms: Fiber-to-the-Home, Radio-over-Fiber, W-Band

I. INTRODUCTION

The need for high speed communication systems for video based interactive and multimedia services are increasing nowadays. Recent studies show that RoF systems are the best solution to satisfy the increasing requirement of high speed data communication. In RoF technology, information signals are transmitted from central station (CS) to base stations (BS) through fiber feed networks. Most of the circuitry for radio frequency (RF) processing are present at the central station and as a result, the base station becomes simple. ROF systems can be integrated with Fiber-to-the-Home (FTTH) to provide high data rate for both wireless and wire-line access. By doing so, baseband and RF signals can be transmitted simultaneously. FTTH replaces existing copper infrastructure and delivers communication signal over optical fiber and is often known as “Future-proof Technology”. It provides high bandwidth and its speed is independent of the distance between end user and telephone exchange unlike the Digital Subscriber Line (DSL) family of technology. Furthermore, life time of fiber cable lasts for around 30 years or more and thus helps in reducing the maintenance cost. W-band Orthogonal Frequency Division Multiplexing (OFDM) optical millimeter wave generation using non-upling technique has been proposed by S. E. Alavi et al. [1]. Wband which ranges between 75-110 GHz has many advantages. It provides high data rate, Network security, low atmospheric attenuation and moreover, helps to avoid spectral congestion in low frequency bands. In another paper, a hybrid system which transmits one wired and two wireless signals using

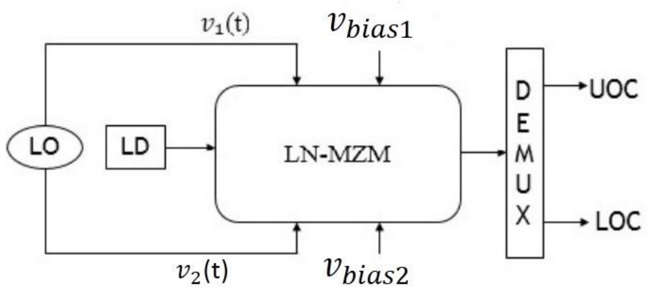

Fig. 1. Schematic diagram of optical carrier generation, LO: local oscillator, LD: laser diode, LOC: lower optical carrier, UOC: upper optical carrier, DEMUX: demultiplexer, LN-MZM: lithium niobate mach zehnder modulator.

Frequency doubling and quadrupling schemes is proposed [2]. A system which uses 24.75 GHz local oscillator to generate 60 GHz wireless signal has been proposed by Tong Shao et al. [3]. C. W. Chow et al. [4] proposed a system which integrates wireline and wireless access. Cascaded single drive MZMs can be used to generate W-Band direct detection system [5], [6]. 64 GHz optical millimeter wave can be generated with nested LiNbO3 modulators and 8 GHz local oscillator [7], [8]. A system employing frequency-doubling optical millimeter-wave generation scheme has been proposed by H. C. Chien et al. [9].

In this paper, a hybrid system integrating FTTH and 90 GHz wireless access is proposed. 90 GHz is generated using nonupling technique employing a low frequency local oscillator. Using a single dual drive MZM, both wireline baseband and 90 GHz wireless signals can be transmitted simultaneously. Advantage of this hybrid system is that it uses only a 10 GHz local oscillator and a single MZM for both wireline and wireless transmission.

This paper is organized as follows. Section II briefly presents the principle of optical carrier generation. In section III, a hybrid system involving both wireline and wireless access is presented. Simulation results are addressed in section IV. Finally, conclusions are drawn in section V.

II. GENERATION OF OPTICAL CARRIERS

Schematic diagram of optical carrier generation is shown in Fig. 1. External modulation is the principle behind the generation of optical carriers [1].

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* Correspondence Author (s)
Joseph Zacharias, Department of Electronics, Rajiv Gandhi Institute of Technology (RIT), Kottayam (Kerala)-695035, India.
Celine George, Department of Electronics, Rajiv Gandhi Institute of Technology (RIT), Kottayam (Kerala)-695035, India.
Vijayakumar Narayanan, Department of Electronics, Government Engineering College, Kunnukuzhy, Thiruvananthapuram (Kerala)-695035, India.

Bias voltages and RF clocks are given to the two arms of LiNbO3 MZM (LN-MZM). v_{bias1} and v_{bias2} are the bias voltages. $v_1(t) = v_{LO} \cos \omega_{LO} t$ and $v_2(t) = v_{LO} \cos(\omega_{LO} t+\theta)$ are two RF sinusoidal clocks which differs by a clock phase difference θ between the two

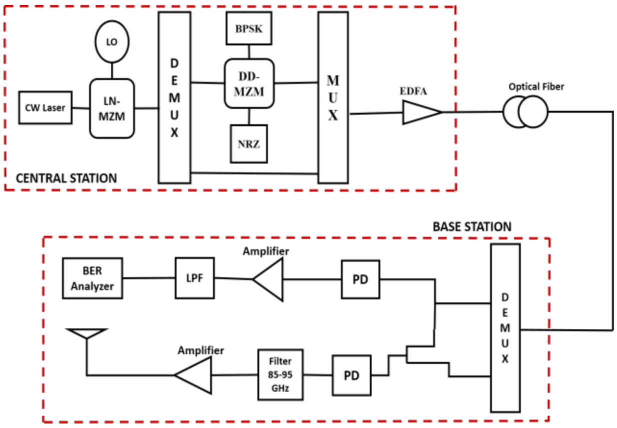

Fig. 2. Hybrid RoF downlink system. LO: local oscillator, CW: continuous wave, DEMUX: demultiplexer, DD-MZM: dual drive mach-zehnder modulator, MUX: multiplexer, EDFA: erbium doped fiber amplifier, PD- photodetector, LPF: low pass filter

TABLE I PARAMETERS OF CARRIER GENERATION

Parameter	Result
$\theta=\pi$	$\cos(2n\theta)=1$, $\cos(2n-1)\theta=-1$, $\sin(2n\theta)=\sin(2n-1)\theta=0$
$v_{bias1}= v_{bias1}= 0$	$\psi_1=\psi_2=0$
$v_{\pi}=4$, $v_{LO}=7.03$	m=5.52
m=5.52	J_0(m)=0, J_2(m)=-0.12, J_4(m)=0.397

TABLE II DESIGN PARAMETERS

Device	Specification
Laser diode	ω_o =193.1 THz
Local oscillator (LO)	ω_{LO} =10 GHz
LN-MZM	$v_{bias1}=v_{bias2}=0$, v_{π}= 4 V

arms of the LN-MZM. ω_{LO} and v_{LO} , is the angular frequency and amplitude voltage of local oscillator respectively. The output field after LN-MZM can be as follows:

$$E_{MZM} = \frac{E_{cw}}{2}\cos[\omega_0 t + m\cos(\omega_{LO} t+\theta)+\psi_2] + \frac{E_{cw}}{2}\cos[\omega_0 t + m\cos(\omega_{LO} t)+\psi_1] \quad (1)$$

where, $E_{CW} = A_{CW}\cos\omega_0 t$ is a continuous wave lightwave with amplitude A_{CW} and angle frequency ω_0 . $m = (\pi/V_\pi)\, v_{LO}$ is the phase modulation index. $\psi 1 = (\pi/V_\pi) v_{bias1}$ and $\psi 2 = (\pi/V_\pi) v_{bias2}$ denotes constant phase shifts induced by the bias voltages. By expanding Equation 1 using Bessel function and applying parameters given in Table I, Equation 1 can be reduced as follows:

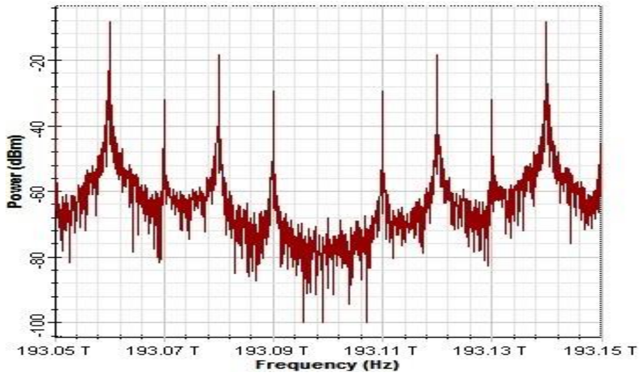

Fig. 3. Output spectrum of LN-MZM

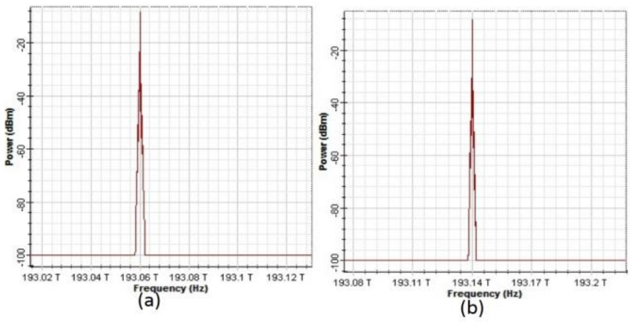

Fig. 4. (a) Lower optical carrier and, (b) Upper optical carrier obtained after DEMUX

$$E_{MZM} = 2E_{CW}\cos(\omega_0 t)\sum_{n=1}^{\infty}(-1)^n J_{2n}(m)\cos(2n\omega_{LO} t) \quad (2)$$

Since J_4 (m) has greater value compared to others, two components of the spectrum which are 80 GHz apart can be demultiplexed to produce lower optical carrier (LOC) and upper optical carrier (UOC). The output spectrum after demultiplexer (DEMUX) is given as follows:

$$E_{demux} = E_{cw} J_4(5.52)[\cos(\omega_0 + 4\omega_{LO})t + \cos(\omega_0 - 4\omega_{LO})t] \quad (3)$$

Equation 3 suggests that the LOC and UOC obtained at the output of demultiplexer is apart by $8\omega_{LO}$.

III. SYSTEM DESIGN

Fig. 2 shows the schematic diagram of hybrid RoF downlink system. At the CS, light source used is a continuous wave (CW) laser. CW laser emits light at 193.1 THz. LN-MZM is biased at null point for carrier suppression and its modulation index is set at m= 5.52.

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It generates two carriers which are $8\omega_{LO}$ apart, say lower and upper optical carriers (LOC and UOC respectively). ω_{LO} is the local oscillator's angular frequency and is set at 10 GHz. Thus, two carriers with frequency interval of 80 GHz are obtained at the

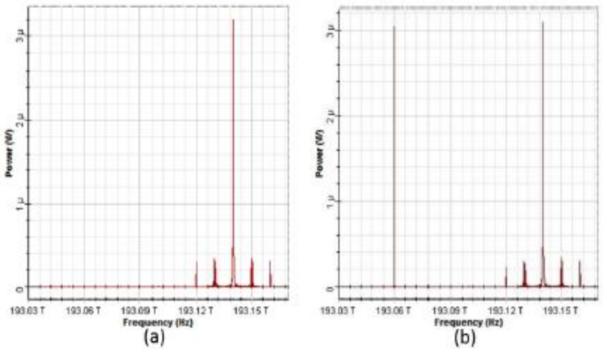

Fig. 5. Output of (a) MZM (b) MUX

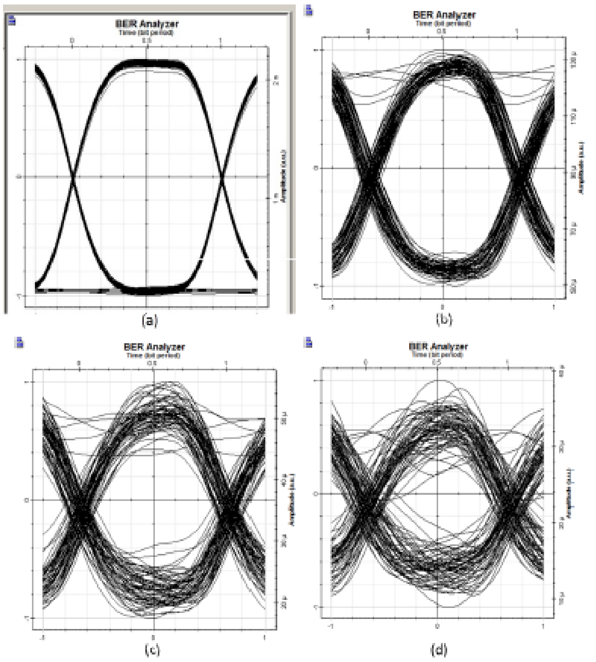

Fig. 6. Eye diagrams related to (a) BTB, (b) 50 km, (c) 70 km, (d) 80 km

TABLE III BER Vs FIBER LENGTH FOR BASEBAND SIGNAL

Fiber length	BER
BTB	1.727x 10^{-75}
20 km	5.863 x 10^{-23}
60 km	1.57 x 10^{-10}
70 km	0.00044

output of LN-MZM. The two carriers are then separated using a demultiplexer of bandwidth 40 GHz. The UOC and LOC are at 193.14 THz and 193.06 THz. Design parameters for the simulation is shown in Table II. The UOC is modulated using dual drive (DD)-MZM. The broadband BPSK signal at 10 GHz is applied to one arm of the DD-MZM and the other arm is fed with non-return to zero (NRZ) signal. NRZ signal is fed for baseband modulation. The unmodulated LOC and modulated optical signals are then multiplexed using a multiplexer (MUX). Then, the hybrid signal obtained after multiplexer is transmitted over optical fiber. At the base station, received signal is demultiplexed using demultiplexer. One of the demultiplexer output is directly send to a photodetector (PD) of bandwidth 10 GHz. Thus, the baseband signal is detected and this signal can be fed for FTTH application. For millimeter wave (mmW) detection, a PD with a bandwidth of 90 GHz is used. Detected wireless signal at 90 GHz is then transmitted through antenna to the customer units.

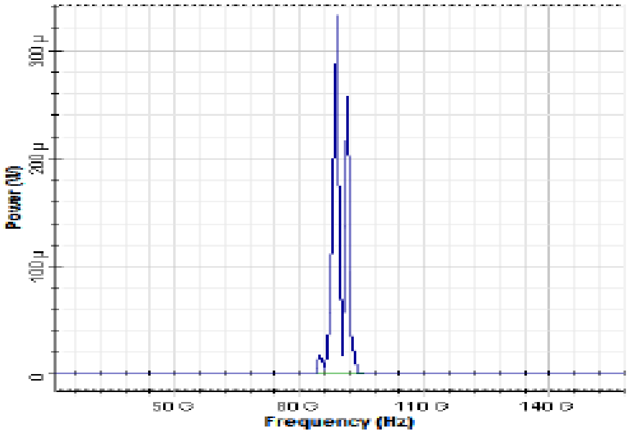

Fig. 7. Signal received at 90 GHz

IV. SIMULATION AND RESULTS

Optisystem 14 is used to simulate the hybrid RoF downlink system. This system can transmit both wireless and wireline data simultaneously upto a distance of 70 km with acceptable BER.

LOC and UOC are generated by LN-MZM (Fig. 3) at 193.06 and 193.14 THz and carriers are separated by DEMUX (Fig. 4). Output spectrum obtained after DD-MZM is shown in Fig. 5 (a). Output obtained after multiplexing unmodulated LOC and output of DD-MZM is as shown in Fig. 5 (b). At the baseband receiver, received signal detected using PD is send to BER analyzer. The simulation is repeated for different fiber lengths of 50 km, 70 km and 80 km. The simulation is also performed for back to back (BTB) that is, without fiber. Eye diagrams obtained for different fiber lengths are as shown in Fig. 6. BER obtained for different fiber lengths are given in Table IV. From Table IV, the BER is acceptable upto a fiber length of 70 km. Photodetector at millimeter wave detection section detect wireless signal at 90 GHz and is shown in Fig. 7.

V. CONCLUSION

Based on the obtained results from the simulation, it can be understood that the wireless and wireline signal can be transmitted simultaneously up to a distance of 70 km with acceptable BER. The advantage of this system is that it uses only a 10 GHz local oscillator and thereby, attaining 90 GHz signal using non-upling technique. Another advantage of this System is that it uses only a single modulator to generate hybrid signal and thus, reducing the overall cost of the system.

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