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Performance Evaluation of Optical Carrier Suppression Radio over Fiber System Through Modulation Index Enhancement

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Abstract – **The performance of optical carrier suppression (OCS) radio over fiber (RoF) system is evaluated through tuning the modulation index of Mach-Zehnder modulator, and two different data modulation schemes are considered. The quantitative simulation results validate that there exist an optimum modulation index, and the system performance could be improved if the data signal is modulated on only one of two sidebands.**

Keywords-Microwave photonics; Radio over fiber; Optical carrier suppression; Modulation index;

I. INTRODUCTION

The demand of the wideband radio access services makes the use of the millimeter band radio necessary for the future wireless telecommunication [1,2]. ROF technology can make the advantages of the optical fiber transmission and millimeter-wave combined, relieve the problems of wireless millimeter-wave system's limited transmission distance [1~4]. To produce high quality millimeter-wave signal is the key technologies to make the millimeter-wave ROF system realized [3,4]. Different prototypes of MZM can generate the optical mm-wave with different spectra, such as double sideband(DSB), optical carrier suppression(OCS), and single sideband(SSB),while each of them has different immunity capacity for the fiber dispersion [3-5].The DSB optical mm-wave suffers not only from the fading effect but also from the time shift of the code caused by the sidebands' walk-off[6].Although the OCS optical mm-wave and the SSB optical mm-wave with the signal carried by both the optical carrier and its sideband is immune to fading, time shift of the code limits its transmission[4–6].

In this paper, we perform simulation investigation of two OCS RoF systems with different data modulation scheme, and the influence of modulation index (MI) of Mach-Zehnder modulator (MZM) on the system performance is quantitative analyzed and discussed. The obtained results can provide assistance for RoF system design.

II. PRINCIPLE OF OCS ROF SYSTEM

The schematic diagram of traditional OCS RoF system is shown in Figure 1.

There are an optical millimeter-wave generation module and a data modulation module at central station, transmission module and a receiver module at base station.

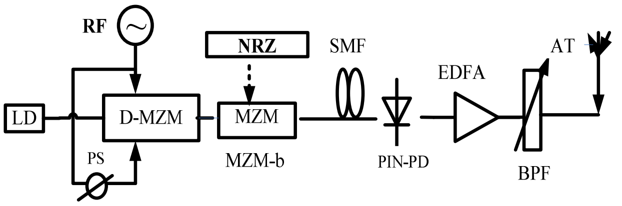

Figure 1. Schematic diagram of traditional OCS RoF system. LD: Laser diode, MZM: Mach-Zehnder modulator, RF: Radio frequency, PS: Phase shifter, SMF: Single mode fiber, PIN-PD: PIN Photoelectric detector, EDFA: Erbium doped fiber amplifier, BPF: Band pass filter, AT: Antenna terminal.

The output of the laser can be expressed as $E(t)=E_0\exp(j\omega_c t)$, Where E_0 and ω_c is optical carrier amplitude and angular frequency, respectively. The output electric field of the D-MZM modulator is:

$$E_{out}(t)=\frac{E_i}{2}\left\{\exp[j\frac{\pi V_1(t)}{V_\pi}]+\exp[j\frac{\pi V_2(t)}{V_\pi}]\right\}\exp(j\omega_c t) \quad (1)$$

Where $V_i(t)=V_{dci}+V_{RF}\cos(\omega_{RF}t+\phi_i), i=1,2$ represents drive signal applied to each arm of the device and V_π is the switching voltage. Ignoring the fiber loss and nonlinear effects, the light field can be expressed as:

$$E(0,t)=\frac{E_0}{\sqrt{2}}\exp(j\phi_d)\sum_{n=-\infty}^{+\infty}\{2J_n(m)\cos(\phi_V+n\phi_c)\times \exp\left[j\left(\omega_c t+n\omega_{RF}t+n\phi_p+n\pi/2\right)\right]\} \quad (2)$$

Where $m=\pi V_{RF}/V_\pi$ is the modulation index of MZM modulator, and Jn(m) is the Bessel function of first kind and order n.

$$\phi_d=\pi\left(V_{DC_1}+V_{DC_2}\right)/2V_\pi$$
$$\phi_v=\pi\left(V_{DC_1}-V_{DC_2}\right)/2V_\pi$$
$$\phi_p=\left(\Phi_{RF_1}+\Phi_{RF_2}\right)/2$$
$$\phi_c=\left(\Phi_{RF_1}-\Phi_{RF_2}\right)/2$$

$m = \pi V_e / V_\pi = m(1 \pm \mu)$, μ represents unbalanced ratio of drive signal applied to each arm of the MZM modulator.

A method to generate frequency-doubled millimeter-wave signals using CS-DSB optical modulation technique was proposed by O'Reilly *et al.* in 1992[9]. A 40-GHz millimeter-wave signal was generated when the MZM was driven by a 20-GHz microwave signal. Such a system was employed for a remote delivery of video services.

For the OCS optical subcarrier modulation, the D-MZM is biased at the linear point, $V_{dc1} - V_{dc2} = V_\pi$, with a phase shift between electrodes of $\phi_1 - \phi_2 = \pi$.

After using up Optical filter (OF) filters out the higher harmonic, can obtain the OCS signal, the expression of OCS signal is：

$$E_{OCS}(0,t) = \frac{E_0}{\sqrt{2}} J_{-1}(m) \exp\left[j\left(\omega_c t - \omega_{RF} t + \phi_d + \phi_p + \frac{\pi}{2} \right)\right] + \frac{E_0}{\sqrt{2}} J_1(m) \exp\left[j\left(\omega_c t + \omega_{RF} t + \phi_d + \phi_p + \frac{\pi}{2} \right)\right] \quad (3)$$

The first term is -1 order optical millimeter wave sideband component, and the second term is +1 order optical millimeter wave sideband component. We can find that the frequency interval of the two components is two $2f_{RF}$.

In order to improve the system performance of OCS RoF link, the modified approach is employed. The key issue of the modified scheme is that data signal is modulated on only one of optical millimeter wave sidebands after separation of the two sidebands. The principal diagram of the improved OCS RoF system is shown in Figure 2.

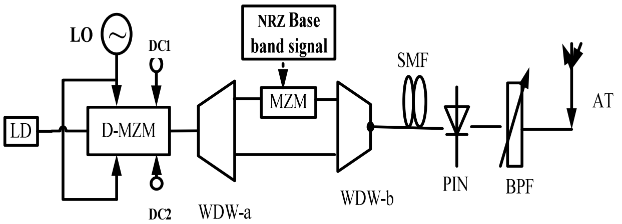

Figure 2. Schematic diagram of traditional OCS RoF system. EDFA is Erbium doped fiber amplifier. LP is Low pass filter. BPF is Band pass filter. BERT is Bit Error Rate Tester.

III. SIMULATION AND DISCUSSION

To evaluate the system performance in the OCS ROF link considering the tuning of the modulation index of MZM on, simulation calculation has been respectively performed for the following two different situations by using the commercial software package OptiSystem.

In the first situation, the principal diagram is shown as Figure 1. Non-return-to-zero (NRZ) data signal is modulated on two optical millimeter wave sidebands, and incoherent detection is employed to achieve simple and cost-effective receiver. The system parameters are set as follows: The center frequency of LD is 193.1THz; 3dB bandwidth of LD is 10MHz. The data rate is 2.5 Gbit/s and the RF frequency is 20GHz. We assume modulator is the ideal $LiNb_3$ Mach-Zehnder Modulator and the switching voltage of MZM is 4V. The attenuation of SMF can be compensation by EDFA. The fiber dispersion is set to 16.75 ps(nm.km). The responsively of photodetector is 1 A/W. The output signal of PD will be filtered by the band-pass filter (BPF) with center wavelength of 40 GHz.

For a distribution system with a transmission distance of 30 Km over a SMF link, the maximum Q factor versus modulation voltage of MZM in the traditional OCS RoF link is plotted in Figure 3. It is clearly seen that maximum Q factor varies with the tuning of modulation voltage of MZM, and there exist an optimum modulation voltage (0.9V) corresponding to best system performance (Q factor = 7.6).

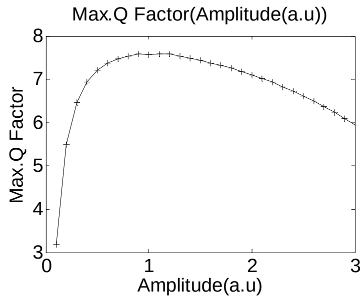

Figure 3. Maximum Q Factor versus modulation voltage in the traditional OCS RoF system

For the traditional OCS RoF link with optimum modulation voltage 0.9V, the maximum Q factor versus transmission distance is plotted in Figure 4. As can be seen from the figure, to achieve Q factor = 6 (BER = 10^{-9}), the maximum transmission distance is about 40 Km.

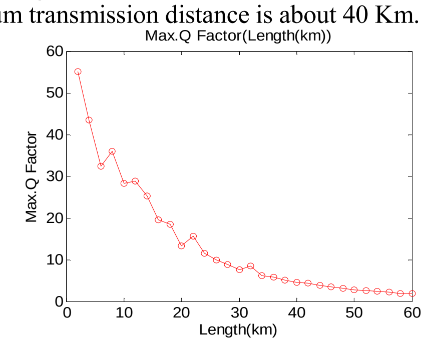

Figure 4. Maximum Q Factor versus transmission distance in the traditional OCS RoF system with optimum modulation index

In the second situation, the principal diagram is shown as Figure 2. NRZ data signal is modulated on one of two optical millimeter wave sidebands, and the system parameters are set as those of the first situation, incoherent detection is also employed.

For a distribution system with a transmission distance of 30 Km over a SMF link, the maximum Q factor versus modulation voltage of MZM in the improved OCS RoF link is plotted in Figure 3. As can be also from the figure, there exist an optimum modulation voltage corresponding to best system performance, and the optimum modulation voltage and maximum Q factor is 2.3 and 50.4, respectively.

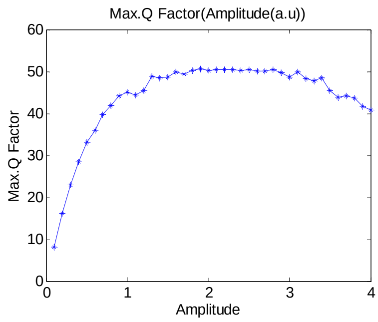

Figure 5. Maximum Q Factor versus transmission distance in the traditional OCS RoF system with optimum modulation index.

For the improved OCS RoF link with optimum modulation voltage 2.3V[10], the maximum Q factor versus transmission distance is plotted in Figure 4. It is clearly seen that the maximum transmission distance is about 160 Km to achieve Q factor = 6 (BER = 10^{-9}).

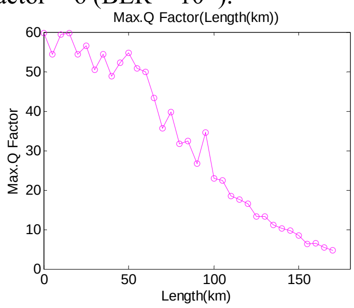

Figure 6. The relationship of bit error rate power and transmission distance in traditional transmission system

The eye diagram of improved OCS RoF system with different transmission distance is shown in Figure 7, and the transmission distance is 0 km, 30 km, 60 km, 90 km, 120 km, 170 km, respectively. It can be seen from the figure that the eye diagram was obvious and opened even transmission distance reach astonishing 120 km. however, the eye diagram was not so obvious as the transmission distance reach 170 km.

IV. CONCLUSIONS

In conclusion, the system performance of OCS RoF link using different data signal modulation scheme is transmission distance. quantitative analyzed and simulated, and optimization of modulation index of MZM is considered. The theoretical and simulation results show that system performance could be enhanced by tuning modulation voltage of MZM, and result in equal sideband optical power. In addition, transmission distance could be extended markedly if the data signal is modulated on only one of the two sidebands.

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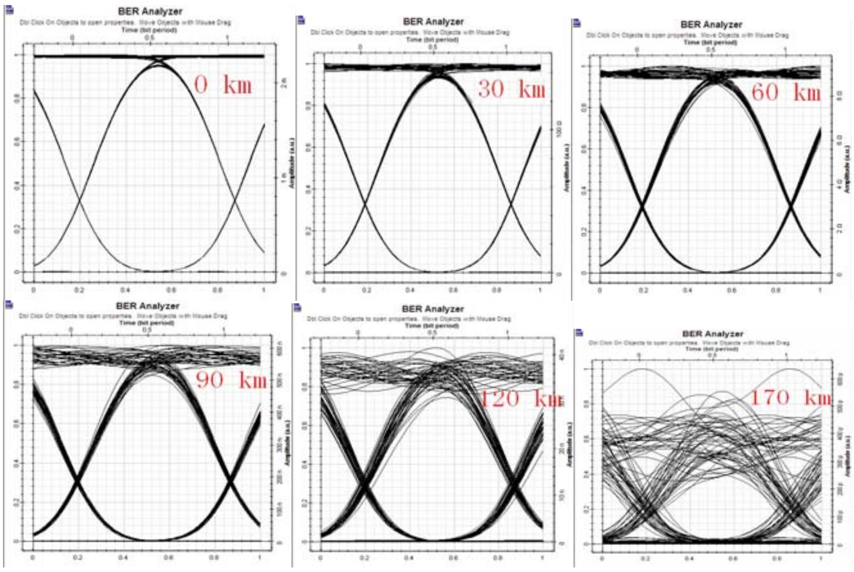

Figure 7. The eye diagram of improved OCS RoF system with different References