Transmission of LTE signals using optical frequency multiplication by millimeter-wave photonic technology

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Abstract-In this paper, performance of long term evolution (LTE) over fiber system is investigated by optical frequency multiplication (OFM) method to generate high-order millimeter-wave (mm-wave) using a dual-electrode Mach-Zehnder modulator (DE-MZM) in radio over fiber. Here, optical double sideband subcarrier (DSBSC) scheme is adopted to overcome fiber dispersion-induced RF power fading. Experimental results demonstrated that error vector magnitude (EVM) can achieve less than 13.5% with 16QAM LTE signal in a wireless transmission distance of 1m.

Index-Mach-Zehnder modulator, Long Term Evolution, optical frequency multiplication (OFM), radio over fiber.

I. INTRODUCTION

With the fast development of wireless access technology and mobile multimedia services, customers’ demands for the transmitting quality of voice, graphics, data and high data-rate wireless communications have been increasing. In the next-generation broad band access network, communication wave band has already been extended to millimeter-wave band. The 60GHz wireless signal is in the 7GHz license-free band, but it restricted by transmission distance and the oxygen absorption.

In order to improve the shortcoming from 60GHz wireless signal, we use Radio over fiber systems to generate and transmit 60GHz modulated with efficient modulations. RoF has been considered as expecting technology for the composition of future high capacity wireless signals such as millimeter-wave wireless communication. [1-3]

Optical RF signal generation is using DE-MZM which is based on single-sideband (SSB), double-sideband (DSB), and double-sideband with carrier suppression (DSBCS) modulation have been discussed[4-6]. Recently, the DSBCS modulation have the best receiver sensitivity and overcome periodic performance fading from fiber dispersion in the millimeter-wave range.

II. STRUCTURE

In this paper, we proposed composition of optical modulation, describing in Fig.1 continuous wave (CW) light from tunable laser source (Agilent/HP 8168F) of 0dBm optical power with a line width of 0.14nm injected to a DE-MZM biased at quadrature and driven by an RF signal of frequency 14GHz which is up-converted with 3.2GHz LTE signal. The MZM has 4.5dB insertion loss, 25dB extinction ratio. The modulated optical signal was transmitted through an SMF fiber. The erbium-doped fiber amplifier (EDFA) has been used for recompensing fiber attenuation. The optical signal was detected and filtered by a high-speed PIN photodiode (u’t XPD V312R) with 3dB bandwidth of 70GHz and responsivity of 0.67A/W and measured on RF spectrum analyzer. After that we used antenna had 56GHz to 64GHz bandwidth to transmit 1 meter in free space. The signal received by antenna was filtered by low noise amplifier and 56GHz to 64GHz band pass filter. Then the signal was down-converted by 56GHz RF signal and measured by LTE spectrum analyzer.

DSBCS can overcome periodic performance fading from fiber dispersion. Unfortunately, fabrication of MZM can not manufacture balance MZM. The unbalance MZM causes the demodulated signal will have periodic power drop at different fiber length. The current of electrical signal detected from PIN photodiode is [7]

$$I = \frac{ef}{2} P_{in} R(2nf_{RF}) e^{-\alpha l} (y^2 - 1) J_n(2\pi m_{RF} \cdot \sin \phi).$$ (1)

I is the current induced by the n-th order of harmonics, $R(\cdot)$ is the frequency response of the photodetector. Land $\alpha$ are the fiber length and fiber loss, $\phi$ is the phase defined by $\phi = -\pi l D(\lambda) \cdot n f_{RF} / c$, where D is the fiber dispersion, so
received electrical signal will be affected by RF signal frequency and fiber length.

III. EXPERIMENTAL RESULT

The experimental setup is shown in Fig.1. We revised polarization controller to achieve DSBCS modulation. Fig.2 (a) is optical signal from output of MZM. We use polarization controller (PC) to suppress carrier signal and let right second harmonic and left second harmonic to create quadruple-local oscillation frequency and bitting 56GHz electrical signal showed in Fig.2(b). There is a paper use interleave to filter the second harmonic and carrier between second harmonics[8]. Interleave will add the cost of system, so our system have lower cost than others.

![Image](image1.png)

Figure 2. (a) Optical spectrum from DE-MZM output by DSBCS modulation. (b) Demodulated 56GHz electric signal by PD.

To test and verify the effect of (1) using our proposed technique. We have measured the demodulated signal from back-to-back (BTB) to 11km fiber length showed in Fig.3(a). We can see the power drop significantly at 9 km which match the result of simulation. This phenomena can be explained by the different distance of fiber length dispersion, and has been simulated in the Ref [7].

![Image](image2.png)

Figure 3. (a) The phenomenon of demodulated signals from BTB to 11 km fiber length. (b) The EVM of demodulated LTE signals from BTB to 11 km fiber length.

Besides the sine-wave signal test, we use LTE generator (R&S SMBV100A) producing QPSK, 16QAM, and 64QAM LTE signal up-converted on 14GHz RF signal to inspect our transmission system. The result is showed in Fig.3(b). The demodulated LTE signal is same as sine-wave signal will have a tarp at 9 km fiber length, but the EVM is less than 13.5% which is the minimum standards of 16QAM in the LTE specification. The outcome displays our system having a good performance with LTE 16QAM signal. In addition, we have measured different bandwidth 3MHz, 5MHz, 10MHz, 15MHz, 20MHz LTE 16QAM signals. The result is showed in Fig.4(a). The EVM of our system performance is less than 13.5%. Fig.4(b) shows the constellation of demodulation LTE signal with 20MHz bandwidth.

![Image](image3.png)

Figure 4. (a) The EVM of different bandwidth LTE 16QAM signals. (b) The constellation of demodulation LTE signal with 20MHz bandwidth in different modulation.

IV. CONCLUSION

In this work, we use DSBCS modulation to multiply high-order millimeter-wave and we use PC to suppress carrier that can reduce the cost of system. We discovered the demodulated signal power will have a periodic power drop at particular fiber length. We experimented and simulated at 56GHz and the result shows that the power drop significantly at 9 km which match the result of simulation. In order to check the performance of our proposed system, we added LTE signals in the system. The EVM of 16QAM LTE signals were all less than 13.5% achieving the minimum standards of 16QAM in the LTE specification. So our proposed system can transmit signals in 1 meter free space from BTB to 11 km fiber distance.

REFERENCES