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# RF Output Power Improvement Using Heterodyne Technique for Radio-on-Fiber Down-link Transmission System Eliminating Electric Power Supply at Base Station

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*Abstract - RF output power improvement using heterodyne technique for radio-on-fiber down-link transmission system at base station is proposed and demonstrated. We have successfully improved the RF power of about 7.5 dB without electric power supply facilities.*

## Introduction

In future access network, radio-on-fiber (ROF) transmission system is one of the important techniques which deliver broadband radio-frequency (RF) signals for wireless communications [1, 2]. In this system, more base stations (BSs) are needed due to higher transmission loss as the transmission speed becomes higher. Thus, in order to implement ROF system, simple and cost-effective configuration must be required at each BS. So far, various types of simplified BS scheme have already been proposed [3, 4]. In particular, the electric power supply facilities in each BS are a big obstacle for the construction and maintenance of the BSs. To overcome this problem, we proposed a novel ROF system, which eliminates the electric power supply facilities at the BS by means of the power delivery, which feeds optical power over optical fiber from central station (CS) [5]. However, further performance improvement is required to implement the proposed scheme more effectively. Heterodyne technique is a practical approach to improve the transmission performance for ROF systems. Previously, the elimination of dispersion effect in fiber [6] and 60-GHz millimeter wave transmission [7, 8] were reported using such technique.

In this paper, we present RF output power improvement at the BS for ROF down-link transmission system by means of heterodyne technique for the optical transmission signal. Using the proposed scheme, the RF output power is improved approximately 7.5 dB without adding to electric power supply facilities such as low noise amplifier at the BS.

## Operation principle and experimental setup

The experimental setup of ROF down-link transmission system is depicted in Fig. 1. The 2.45-GHz data signal is generated from a signal generator (SG) with WLAN, 54 Mbps, and IEEE 802.11 format, which uses orthogonal frequency division modulation (OFDM) each modulated with 64 quadrature amplitude modulation (64QAM). In the conventional scheme as shown in Fig. 1(a), the optical signal at the wavelength of 1550 nm is directly modulated by an electroabsorption modulator (EAM) biased at 1 7

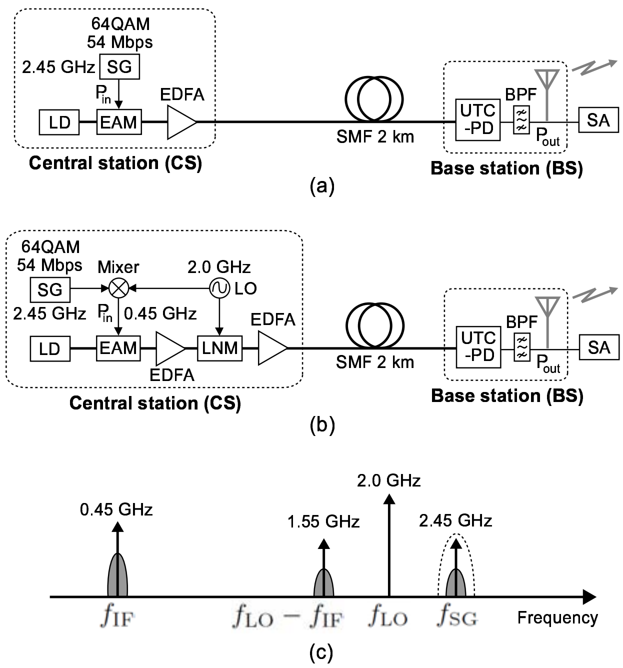


Figure 1: Experimental setup of (a) conventional and (b) proposed ROF down-link system. (c) RF signal spectra.

V. In this scheme, the modulation depth is generally restricted by not only the modulation characteristics of the EAM, but also the bandwidth limits of electrical components. To overcome this problem, we utilize RF heterodyne technique at the CS as shown in Fig. 1(b). The 2.45-GHz data signal is mixed down to 0.45-GHz signal in the microwave region with a 2.0-GHz local oscillator (LO). After the modulation by the EAM, the optical signal is intensity-modulated with the $LiNbO_3$ modulator (LNM) by applying the 2.0-GHz LO signal. Then, the modulation signal is described as

$$\begin{aligned} & P_0 \{1 + m_{\mathrm{a}} \cos(2\ \ f_{\mathrm{IF}} t)\} \times \{G \cdot 1\ \ 2(1 + \cos(2\ \ f_{\mathrm{LO}} t))\} \\ = \ & GP_0\ \ 2 + GP_0\ \ 2 \cdot \cos(2\ \ f_{\mathrm{LO}} t) \\ & + m_{\mathrm{a}} P_0 G\ \ 2 \cdot \cos(2\ \ f_{\mathrm{IF}} t) \\ & + m_{\mathrm{a}} P_0 G\ \ \ \cdot \cos(2\ \ (f_{\mathrm{LO}}\ \ \ f_{\mathrm{IF}}) t) \\ & + m_{\mathrm{a}} P_0 G\ \ \ \cdot \cos(2\ \ f_{\mathrm{SG}} t) \qquad (1) \end{aligned}$$

where $P_0$ is the average optical power of the modulated signal at the output of the EAM, $G$ is the signal gain of the erbium-doped fiber amplifier 1 (EDFA1), including the insertion loss of the LNM, $m_{\mathrm{a}}$ is the modulation depth of the EAM, $f_{\mathrm{LO,\ SG}}$ are the modulation frequency generated by the LO and SG, respectively, $f_{\mathrm{IF}}$ is down-conversion frequency injected into the EAM for the proposed scheme. These signal spectra are shown in Fig. 1(c). At the CS, EDFA2 is employed to set the injected power of 7.5 dBm into the 2 km single-mode fiber (SMF). After the propagation in the fiber down-link, the optical signal is converted to the electrical signal by the unbiased uni-traveling-carrier photo-diode (UTC-PD), and the signal passes through the bandpass filter (BPF) with the center frequency of 2.45-GHz. The received power and quality of the electrical signal are measured by the signal analyzer (SA). In the proposed scheme, the 2.45-GHz data signal described in the $5^{\mathrm{th}}$ term of Eq. (1) is only received by passing through the BPF, as shown in the dashed line of Fig. 1(c). Thus, the improved ratio of the RF output power can be obtained from the signal gain $G$ of the EDFA1. In this experiment, $G$ is set to about 6.0 dB. Thus, higher modulation depth of the proposed scheme is obtained compared to the conventional scheme.

### Experiment and results

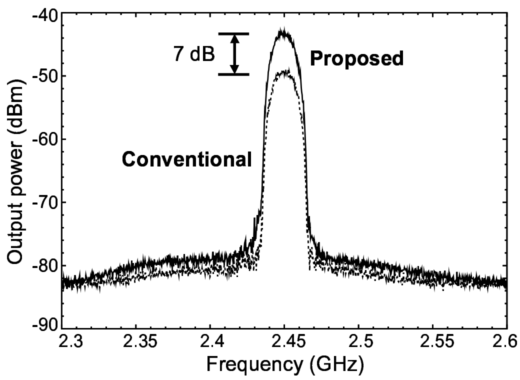


Figure 2: RF output spectra for the cases of conventional and proposed schemes.

Figure 2 shows the RF output signal spectra for the cases of the conventional and proposed schemes when the input data signal power is set to 2 8 dBm. Utilizing the proposed scheme, the peak power of the output spectrum is increased up to approximately 7 dB. No remarkable noise spectral component is observed for the proposed scheme.

The down-link transmission performance is shown in Fig. 3. The transmission performances of both schemes show good linearity characteristics. These results indicate that the RF output power at the BS improves approximately 7.5 dB in the measured overall range of the input RF power without electric power supply facilities. The improved ratio of the RF power is larger than $G$ of 6.0 dB as described in Eq. (1), because the frequency responses of the EAM and the electrical components are also improved by the down-conversion of the RF signal to 0.45-GHz.

Figure 4 shows the bit-error-rate (BER) as a function of the received RF power. Compared to the conventional scheme, the proposed scheme has a little power penalty. We believe that the power penalty is due to the noise of the added EDFA and the characteristics of the LNM. On the other hand, the excess power penalty of approximately 1.5 dB around the lowest BER is much smaller than the power margin of 7.5 dB, which is improved using the proposed scheme. Thus, these results have proved that the proposed scheme is effective to improve the transmission performance for the ROF down-link system.

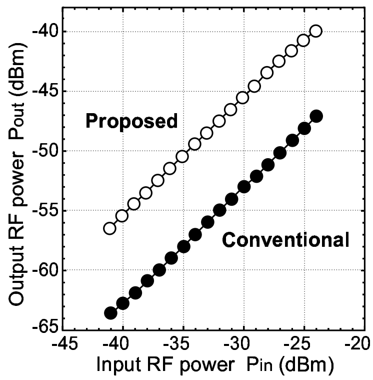


Figure 3: Down-link transmission performance of conventional and proposed schemes.

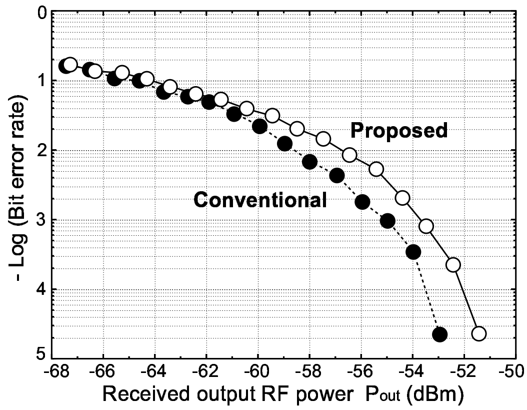


Figure 4: BER curves for the two cases.

### Conclusion

We have successfully improved the RF output power of the electrical signal at the BS for ROF down-link transmission system by means of heterodyne technique. Using this system, the RF output power has been increased up to about 7.5 dB without electric power supply facilities at the BS. The proposed scheme will be also attractive for future ROF system using higher frequency millimeter-wave.

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