

도파로형 광검출소자를 이용한 광전 주파수 하향변환 (Millimeter-wave optoelectronic down-conversion using waveguide photodiode for radio-on-fiber up-link transmission)

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Abstract — We propose a new optoelectronic down-conversion scheme utilizing the nonlinearity of photodiode for radio-on-fiber up-link transmission. The frequency down-conversion from 31GHz RF signal to 1GHz IF signal is experimentally demonstrated by using a photodiode incorporating with 30GHz optical local oscillator (LO). It is shown that the bias condition of photodiode and the input optical LO power strongly affect the conversion efficiency.

I. INTRODUCTION

Radio-on-fiber (RoF) systems have attracted much attention because they utilize low loss and wide bandwidth optical fiber for broad-band data distribution from central station (CS) to remote antenna base stations (BS) [1]. The ultimate goal for these RoF systems is to construct bidirectional links for the applications including indoor wireless LAN and ITS.

For the successful construction of the RoF systems, it is important to design low cost and compact BS transceiver because many BS are required due to the small cell size. Much effort has been done to simplify BS architecture [1-2]. Among them, remote up-conversion schemes incorporating with optical LO are a promising candidate because they eliminate expensive electrical phase-locked LOs and provide the design flexibility for WDM/RoF transmission links [2-3].

Among the several up-link configuration schemes, we believe that the directly modulated laser diode is most suitable optical transmitter from BS to CS because of its simplicity. However, since the direct modulation frequency for laser diode is limited below 10GHz, the frequency down-conversion scheme from millimeter-wave band to intermediate frequency band is required, which make it difficult to realize cost-effective BS transceivers.

We propose and experimentally demonstrate a new optoelectronic down-conversion scheme using the nonlinearity of photodiode incorporating with optical LO source for RoF up-link transmission. Fig.1 shows the RoF up-link transmission links under consideration, where optical LO provides reference carrier frequency for each BS and WDM transceivers are used to transmit IF and

address different BS. A photodiode is used as an optoelectronic down-conversion mixer from RF to IF with optical LO transmitted from CS. This approach avoids usages of electrical mixers and phase-locked LOs operating at millimeter-wave for frequency down-conversion.

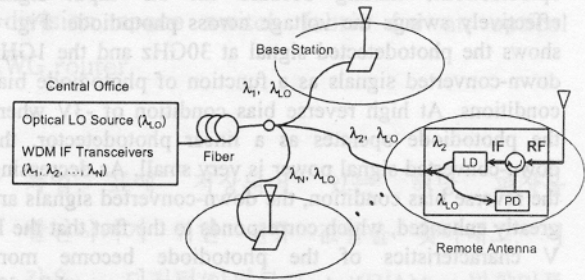


Fig. 1: Proposed radio-on-fiber up-link transmission system

II. EXPERIMENTAL SETUP

For optoelectronic down-conversion experiments, we fabricated the waveguide photodiode which has the responsivity of 0.2A/W and the 3dB bandwidth more than 40GHz. The photodiode allows the maximum input optical power to be less than 10dBm in order to avoid the degraded RF response. The experimental arrangements are schematically illustrated in Fig. 2. The on-wafer RF probe and the bias-tee were connected to apply DC bias and RF signals. The power divider was utilized to measure the down-converted IF signal at 1GHz as well as to apply 31GHz RF signal to the photodiode. The optical LO signal at 30GHz was generated by the double sideband suppressed carrier (DSB-SC) techniques using a Mach-Zehnder external modulator.

II. RESULTS AND DISCUSSIONS

Fig. 3-(a) shows the measured spectrum of 1GHz down-converted IF signal. The photodetected 30GHz optical LO signal and 31GHz RF signal applied to the photodiode are also shown in Fig. 3-(b). In these spectrums, the asterisked

signals are image signals of A-band external harmonic mixer (HP 11970A) used for 30GHz band measurements. The optical LO power was 10dBm and the applied RF power was 0dBm. The bias condition of photodiode was 0V. We obtained 1GHz down-converted signal of -57.5dBm, which indicates 57.5dB conversion loss defined as the ratio of input RF power to down-converted IF power including microwave components losses. During the experiments, we found that the conversion loss was not dependent upon the input RF power but dominated by optical LO power and the bias condition of photodiode.

In our proposed scheme, the nonlinearity of photodiode is utilized for the frequency mixing of RF signals with optical LO. There are several attempts to clarify the origin for the nonlinearity in photodiode [4]. In the experiment, we believe that the nonlinear I-V characteristics of p-n junction in photodiode are major origin for this optoelectronic mixing because the RF input signal effectively swings the voltage across photodiode. Fig. 4 shows the photodetected signal at 30GHz and the 1GHz down-converted signals as a function of photodiode bias conditions. At high reverse bias condition of -3V where the photodiode operates as a linear photodetector, the down-converted signal power is very small. As decreasing the reverse bias condition, the down-converted signals are greatly enhanced, which corresponds to the fact that the I-V characteristics of the photodiode become more nonlinear as the applied voltage gets near to zero bias [3-4]. Therefore, the photodiode as an optoelectronic down-converter should be operated in zero bias condition for maximizing down-conversion efficiency. This figure also shows the influence of input optical LO powers on the down-converted IF signal power. The experimental results indicate that increasing optical LO power is efficiency way to improve conversion efficiency.

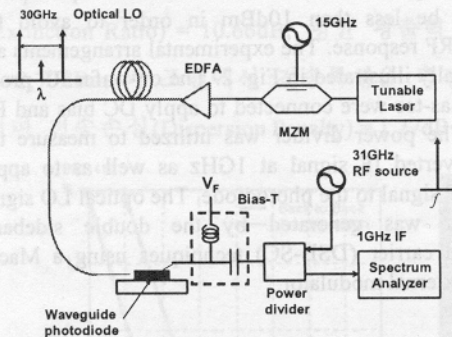


Fig. 2: Experimental setup for optoelectronic down-conversion using waveguide photodiode

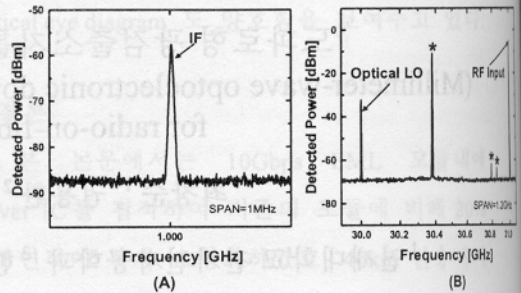


Fig. 3: (a) 1GHz down-converted spectrum (b) photodetected spectrum for 30GHz optical LO and input RF spectrum applied to photodiode. The asterisks indicate image signals caused by external A-band mixer which is used for 30GHz band measurement.

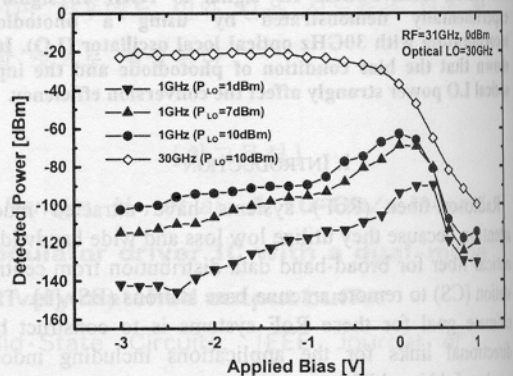


Fig. 4: Dependence of photodetected power at 30GHz and down converted power at 1GHz on bias condition of photodiode

II. CONCLUSION

The optoelectronic down-conversion from 31GHz millimeter-wave to 1GHz IF was firstly achieved by utilizing the nonlinearity of photodiode and the optical LO signal transmitted over optical fiber. The experimental results show that low reverse bias of photodiode and high optical LO power enable the optoelectronic down-conversion efficiency to be improved. This simple optoelectronic down-conversion scheme using only single photodiode is expected to be very useful for simplifying antenna base station architecture in RoF systems.

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