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60GHz Radio-on-Fiber Downlink Systems using Optically Injection-Locked Self-Oscillating Optoelectronic Mixers based on InP/InGaAs HPTs

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Abstract: A 30GHz hybrid-type optically injection-locked self-oscillating optoelectronic mixer is implemented with a high-performance InP/InGaAs heterojunction photo-transistor. Using this mixer as a harmonic up-converter, 60GHz radio-on-fiber downlink transmission of 20Mbps 16QAM data is successfully demonstrated. The link performance is uniform over a wide range of optical LO powers.

OCIS codes: (270.0270) Optoelectronics; (270.1670) Oscillators

1. Introduction

There is a growing need for millimeter-wave wireless data transmission systems which can offer ultra-wide bandwidth. Millimeter-wave wireless communication systems require a large number of antenna base stations due to high transmission loss of millimeter waves in air. Radio-on-fiber (RoF) systems are an attractive solution for this problem because they can provide a network in which numerous antenna base stations are connected through fiber to one central office having centralized functions. In this way, antenna base stations can be simple and cost-effective.
Among several different schemes for realizing millimeter-wave RoF systems, the remote up-conversion scheme is receiving much attention. In this scheme, optical LO signals from the central office are shared among base stations and data are transmitted in the optical intermediate frequency (IF) domain. It can provide immunity to dispersion-induced carrier suppression problems which can be very serious in millimeter-wave RoF systems [1].
In order to perform frequency conversion in the base station, InP-based Heterojunction Phototransistors (HPTs) can be used that can simultaneously perform photo-detection and frequency mixing [2]. We have shown that an InP/InGaAs oscillator can perform the same functions of photo-detection and frequency mixing [3]. Furthermore, this oscillator can be injection-locked by the optical LO resulting in much reduced phase noises. The oscillator phase noise performance is very important for transmitting phase-modulated signals such as PSK and QAM that are often used in wireless applications. Using this optically injection-locked self-oscillating optoelectronic mixer (OIL-SOM) at 10GHz as a harmonic mixer, we successfully demonstrated 30GHz RoF downlink transmission of 20Mbps 16QAM data [3]. In this paper, we report the performance of our upgraded system having a 30GHz OIL-SOM for 60-GHz RoF downlink transmission. In addition, we demonstrate that the link performance does not depend on the optical LO power once optical LO power is beyond a threshold. The optical LO power varies depending on the distance between central office and antenna base station due to fiber loss. Our result demonstrates that OIL-SOM can provide transmission performance regardless of this distance.

2. System Set-up and Measurement Results

For implementing a hybrid-type OIL-SOM, we used a high performance InP/InGaAs HPT having 70nm undoped InP emitter, 50nm carbon doped InGaAs base, and 300nm InGaAs collector. With this HPT, the electrical current gain cutoff frequency and maximum oscillation frequency are 153GHz and 94GHz, respectively [4]. This HPT has responsivity of 0.2A/W at PD-mode where base-emitter junction is shorted. Fig. 1 shows the schematic diagram of 30GHz OIL-SOM based on a InP/InGaAs HPT with a simple feedback loop connecting collector port to base port through a 30GHz-band BPF. At 30GHz, the HPT has AC current gain of 14dB, sufficient for sustained

oscillation even with a 10dB coupler for output at collector port. Although the oscillator is realized with discrete devices in this work, a single-chip oscillator can be easily realized with MMIC technology [5-6].
This free-running oscillator can be optically injection-locked by 30GHz optical LO delivered from the central office. Optical LO is generated with the DSB-SC method using a Mach-Zehnder modulator. The resulting phase noise reduction with optical injection-locking can be observed in Fig. 2. Fig. 3 shows 60GHz RoF downlink data transmission system based on the OIL-SOM. Optical IF signals are generated by direct modulation of a DFB LD with 20Mbps 16 QAM at f_{IF} = 420MHz. Optical LO and IF signals are combined and, after 10km transmission in single-mode fiber, injected into the HPT inside OIL-SOM. Injected optical signals are first photo-detected and then mixed resulting in harmonic frequency up-conversion of f_{IF} into $2f_{LO} \pm f_{IF}$. The output signal of OIL-SOM is passed through a band-pass filter rejecting image and carrier signals and amplified 30dB. The resulting spectrum is shown in inset of Fig. 3.

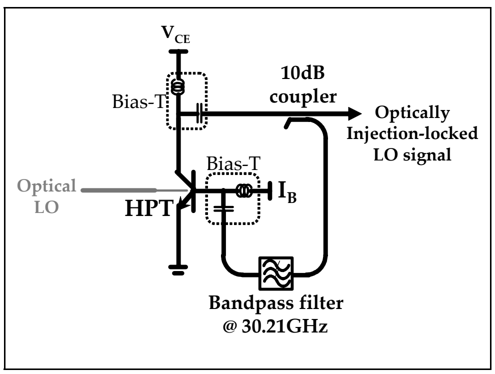

Fig. 1. Schematic diagram of 30GHz OIL-SOM

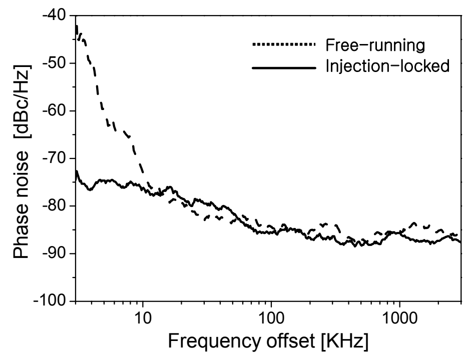

Fig. 2. Phase-noise of free-running and optically injection-locked oscillator

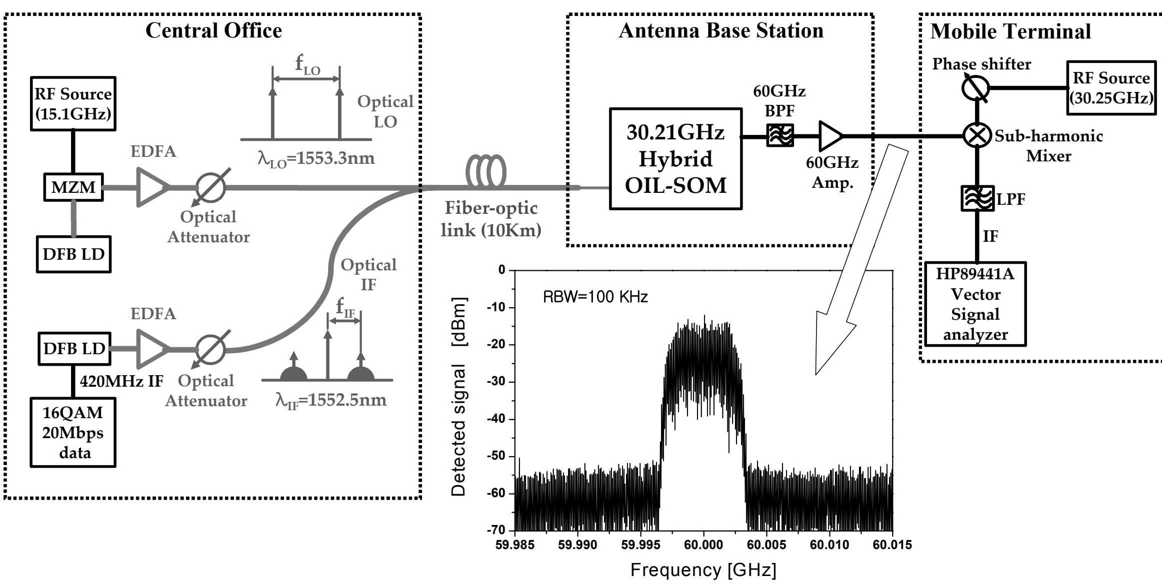

Fig. 3. Experimental setup for 60GHz band downlink data transmission on Radio-on-fiber system using 30GHz band OIL-SOM

In order to evaluate the link performance, 60GHz up-converted signals are frequency down-converted into the IF frequency band using a sub-harmonic mixer. Then, down-converted data are demodulated and analyzed with HP89441A vector signal analyzer by measuring error vector magnitudes (EVMs). When the power of optical LO and IF signals injected into HPT are -3dBm and -6dBm, respectively, the resulting EVM value is 4.74%, which should be sufficient for many applications. Constellation of demodulated data are shown in Fig. 4. EVMs are measured as a function of incident optical LO powers. This is an important measurement since in real RoF systems the optical LO power changes depending on the distance between central office and antenna base station due to fiber loss. Fig. 5 shows that once input optical LO power is larger than -11dBm, the link performance does not change with the optical LO power. This is because as long as the HPT oscillator is optically injection-locked with a sufficient injection optical power, its output power and the mixer efficiency do not change much with the incident optical LO power. This demonstrates that our OIL-SOM can be very useful for real RoF systems as its performance does not depend much on the distance between central office and antenna base stations. It should be noted that the transmission data rate of 20Mbps is limited by the modulation and demodulation equipment available to us, and not by the scheme itself.

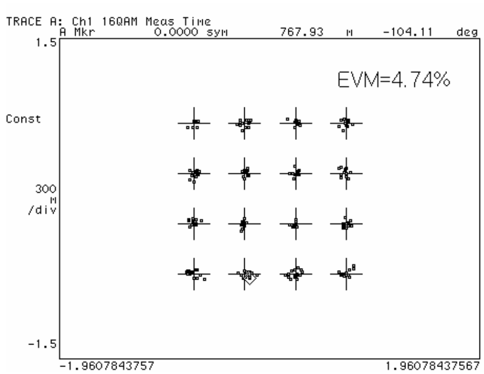

Fig. 4. Constellation for recovered 16QAM data signal

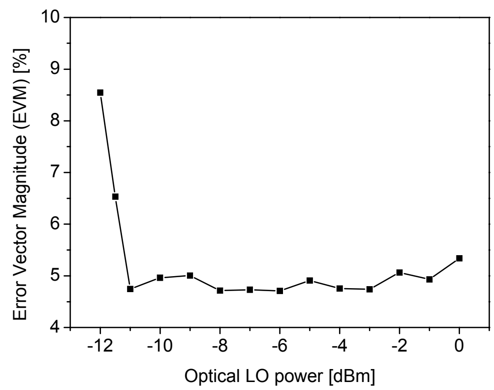

Fig. 5. Error vector magnitude (EVM) as a function of optical LO power to InP HPT

4. Conclusion

We implemented a 30GHz hybrid-type OIL-SOM based on a high performance InP/InGaAs HPT. It has low phase-noise characteristics and provides efficient optoelectronic frequency up-conversion even at 60GHz. Using this OIL-SOM as a harmonic up-converter, we realized 60GHz RoF downlink system based on the remote up-conversion scheme and successfully transmitted 20 Mbps 16QAM data over 10Km optical fiber. Experimental results show that link performance is uniform over the wide range of input optical LO powers.

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