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Technologies for Fiber-fed 60GHz Wireless Systems

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Abstract: We have investigated 60GHz-band optoelectronic-mixers for realizing cost-effective fiber-fed 60GHz wireless systems. Two types of optoelectronic-mixers are review: one based on cascaded semiconductor optical amplifier and electro-absorption modulator, and the other heterojunction bipolar transistors.

OCIS codes: (060.2360) Fiber optics links and subsystems, (230.0250) Optoelectronics

1. Introduction

The main service areas of wireless communication industries are transferring from voice to data services, because the demand for high quality multimedia services is continuously increasing. To meet this demand, there is a need for new types of wireless communication systems that can provide higher capacity. The 60GHz band receives much attention because it can provide wide bandwidth as well as high directivity. FCC in US has allocated 7GHz spectrum between 57 and 64GHz for license-free operation, and recently the Korean government has set 60GHz band as FACS (Flexible Access Common Spectrum). In addition, IEEE 802.15.3 task group is developing WPAN standards in 60GHz band. The wireless communication systems in 60GHz band need a large number of antenna base stations (ABSs) due to high transmission loss of 60GHz waves in the air. Consequently, there is a need for careful network design that can reduce the overall system cost. In addition, much consideration should be given to linking wireless networks to broadband wire-line networks that have been already built. The fiber-fed wireless system is an attractive solution for this, in which optical fiber links numerous ABSs to one central station (CS).

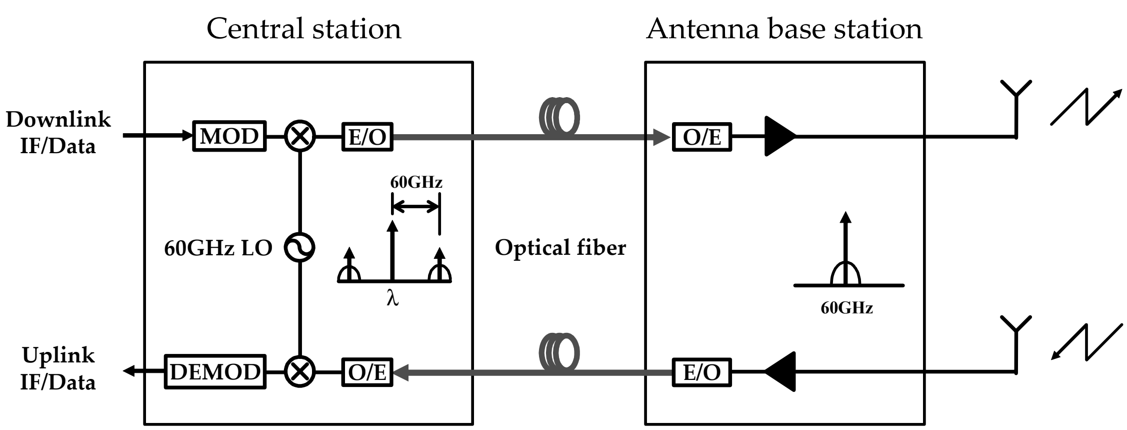

Fig. 1. Fiber-fed wireless system using optical millimeter-wave transmission

The simplest fiber-fed wireless system can be realized based on the optical millimeter-wave transmission technique [1,2]. In this scheme, 60GHz radio signals are optically modulated and transmitted between CS and ABS as schematically shown in Fig. 1. However, the overall system cost can be a problem since optical components operating at 60GHz are too expensive as of yet. In another approach called remote conversion technique [3,4], data signals are transmitted in the optical intermediate frequency (IF) domain and frequency up-converted to 60GHz band in ABSs. In addition, optical distribution of 60GHz local oscillator (LO) signals from CS to many ABSs is possible [5,6], which can eliminate the electrical LO source in ABSs. The key issue for this approach is the realization of efficient and cost-effective optoelectronic frequency up/down converters. We have achieved this using various devices such as a cascaded semiconductor optical amplifier (SOA) and electro-absorption modulator (EAM) [7,8], high-speed transistors including high electron-mobility transistor (HEMT) [9] and heterojunction bipolar transistor (HBT) [10,11], and very recently CMOS-compatible optoelectronic mixers [12].

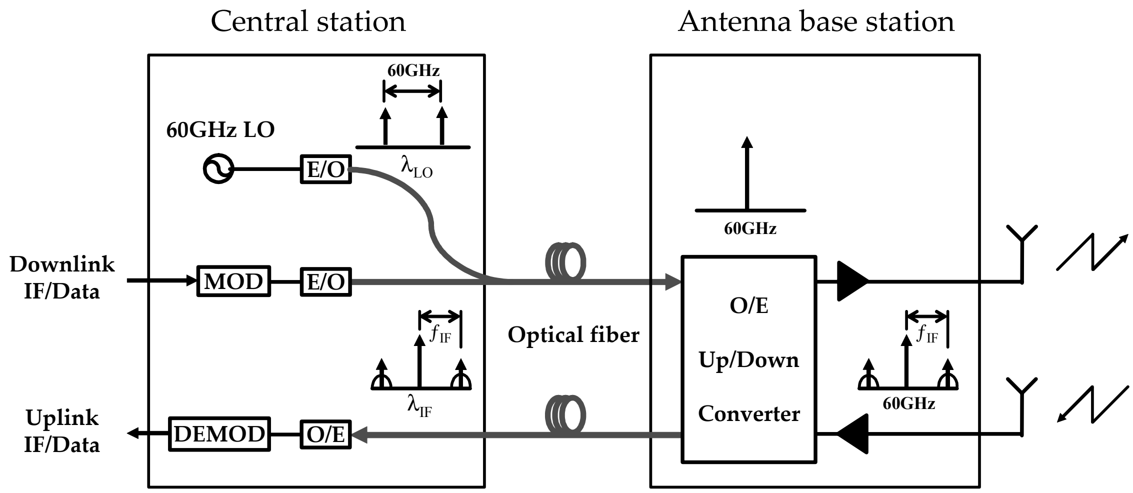

Fig. 2. Configuration of fiber-fed wireless system using remote conversion scheme with optical LO distribution

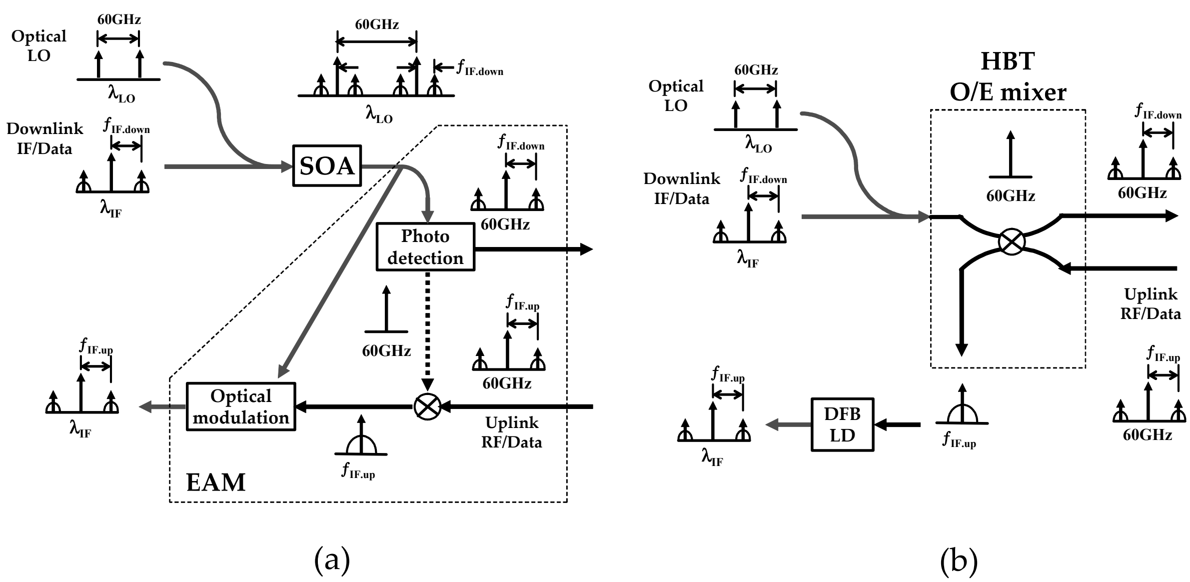

Fig. 3. Operation principles of optoelectronic frequency converters based on (a) cascaded SOA-EAM and (b) HBT

2. Optoelectronic frequency conversion based on cascaded SOA and EAM

As shown in Fig. 3 (a), frequency up-conversion of transmitted optical IF signals into 60GHz in ABSs can be done using optical mixing characteristics of cascaded SOA and EAM [7,8]. When the optical LO signals at λ_{LO} having two optical modes separated by f_{LO} and optical IF at λ_{IF} from CS are injected into SOA in ABS, optical LO signals are cross-gain modulated by optical IF signals and, after photo-detection in EAM, generate frequency up-converted RF signals at $f_{LO} \pm f_{IF}$. In EAM, the externally applied 60GHz band uplink RF signals can be down-converted into IF band by the EAM nonlinearity. Because the cascaded SOA-EAM offers multi-functions of photo-detection, frequency up/down-conversion and optical uplink modulation, ABS can be greatly simplified. We successfully demonstrated bi-directional data transmission of 10Mbps QPSK signals for 60GHz application [8]. In addition, the optical gain of SOA allows the wide range of IF frequencies allowing WDM approach in the network architecture.

3. Optoelectronic frequency conversion bases on HBT*

We have also investigated optoelectronic frequency up/down conversion using InP HBT. InP HBT can simultaneously perform photo-detection of 1.55µm light-wave in the InGaAs base-collector region, amplification, and frequency up/down conversion from and to 60GHz band. Moreover, since high optical responsivity and wide photo-detection bandwidth of HBT allow sufficient photo-detection even in 60GHz, we can utilize this device as a high-performance optoelectronic mixer as shown in Fig. 3 (b). We demonstrated bi-directional transmission of 20Mbps 16QAM signals in 60GHz band including 30Km fiber-optic link and 3m wireless link [10]. The resulting EVM of transmitted signals are 4.53% and 5.35% for uplink and downlink, respectively, with 3dBm optical LO. In addition, the HBT-based fiber-fed wireless system provides the possibility of single-chip realization of the ABS, in which all the necessary electronic components such as amplifiers and filters are monolithically realized along with the optoelectronic mixer.

As a first step toward this monolithic approach, we investigated a HBT-based optically injection-locked self-oscillating optoelectronic mixer (OIL-SOM) and demonstrated 60GHz downlink transmission of 20Mbps 16QAM data for wide range of optical LO power from -11 to 0dBm [11]. For cost consideration, CMOS technology is a very interesting approach. We have very recently realized millimeter-wave band CMOS-compatible optoelectronic mixer CMOS-OEM fabricated by the standard 130nm CMOS process, and demonstrated that CMOS-OEM can detect optically injected 20Mbps 16QAM signals and frequency up-convert them to 30GHz band [12].

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* HBTs used in our investigation were fabricated in NTT Photonics Laboratories