Fibre-supported 60 GHz self-heterodyne systems based on CMOS-compatible harmonic optoelectronic mixers

H.-S. Kang and W.-Y. Choi

Fibre-supported 60 GHz self-heterodyne systems using harmonic optoelectronic mixers fabricated with the 0.18 µm standard CMOS technology are demonstrated. Down-link data transmission of 25 Mbit/s, 32 quadrature-amplitude modulation signals in 60 GHz band is successfully performed.

Introduction: To realise next generation broadband convergence networks, fibre-supported millimetre-wave systems have been widely investigated since millimetre-waves have large bandwidth for wireless links and fibre provides a low-loss and high-capacity data transmission medium [1]. In fibre-supported millimetre-wave systems, broadband data are distributed from a central office to antenna base stations through optical fibre and frequency up-converted millimetre-wave signals are transmitted from antenna base stations to mobile terminals via wireless link. For realisation of these systems, many base stations and mobile terminals are required owing to the small cell size. Accordingly, low-cost implementation of both antenna base stations and mobile terminals is the most important factor. However, as of yet, millimetre-wave components are difficult to realise in a cost-effective manner. Self-heterodyne wireless systems can be a solution to this problem. In self-heterodyne systems, frequency up-converted data are transmitted together with local oscillator (LO) signals from antenna base stations, and down-conversion is performed by mixing of these data and LO signals using square-law devices at mobile terminals [2]. Since frequency down-conversion is performed by self-detection, RF receivers can be simplified without LO signal and the problems related to the phase noise and frequency offset are eliminated [2].

We have previously reported 60 GHz CMOS-compatible harmonic mixers (CMOS-HOEMs), which can perform photodetection of 850 nm optical signal and frequency conversion, simultaneously [3]. By applying these CMOS-HOEMs, additional cost reduction as a result of single-chip integration of antenna base stations with CMOS technology can be possible. In this work, we demonstrate a fibre-supported 60 GHz self-heterodyne system using a CMOS-HOEM. The CMOS-HOEM is fabricated with 0.18 µm standard CMOS technology and 25 Mbit/s, 32 QAM data transmission is performed in the 60 GHz band as a feasibility demonstration.

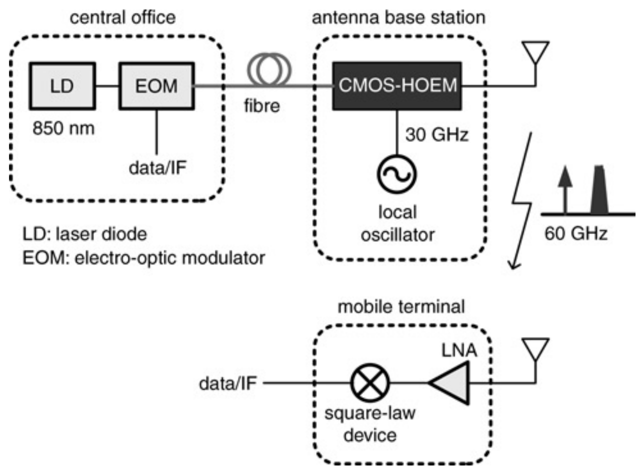

Fig. 1 *Schematic diagram of fibre-supported millimetre-wave self-heterodyne system based on CMOS-compatible optoelectronic mixer*

System architecture: Fig. 1 shows a schematic diagram of a fibre-supported 60 GHz self-heterodyne wireless system based on CMOS-HOEM. At the central office, a data signal at IF band is optically modulated and transmitted through optical fibre. At the base stations, transmitted data are photodetected and frequency up-converted to 60 GHz band using CMOS-HOEM, and then radiated via antennas. In the self-heterodyne system, radiated signals include the LO signal as well as the frequency up-converted data signal. At the mobile terminals, frequency down-conversion is performed by mixing of data and the LO signal using a square-law device. As can be seen in Fig. 1, mobile terminals can be implemented by simple configuration of a low-noise amplifier (LNA) and a square-law device. In addition, frequency stabilisation circuits for the local oscillator are not required in antenna base stations.

CMOS optoelectronic mixer: The CMOS-HOEM is implemented using an Si avalanche photodetector, which provides photodetection of 850 nm optical signal and frequency mixing owing to nonlinear characteristics of avalanche gain [3, 4]. The detailed structure of the fabricated device is shown elsewhere [3]. Fig. 2 shows avalanche gain and photocurrent against applied reverse bias voltage (V_R). Avalanche gain is defined by the ratio of photocurrent at a given bias voltage to primary photocurrent without gain at a V_R of 1 V in the experiment. With increasing V_R, avalanche gain increases owing to the enhanced electric field and has a maximum value of 162 at $V_R = 10.1$ V when the incident optical power is 1 mW. These nonlinear characteristics of avalanche gain cause frequency conversion in CMOS-HOEM.

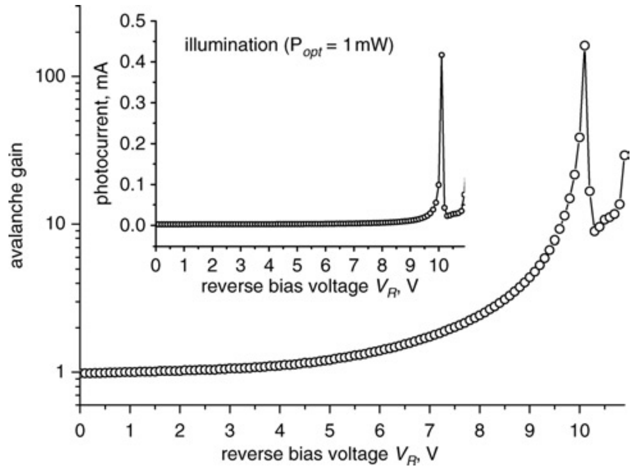

Fig. 2 *Avalanche gain and photocurrent against reverse bias voltage (V_R) when 1 mW optical signal is illuminated*

Experimental results: Utilising CMOS-HOEM, we implement frequency up-conversion to the 60 GHz band. A 30 GHz electrical LO signal is injected into the RF port of the CMOS-HOEM and the modulated optical IF at 100 MHz is illuminated in the device. In the experiment, 3 m long multimode fibre having 50 µm core size is used between the central office and the antenna base station and the incident optical power to the CMOS-OEM is about 1 mW. Fig. 3*a* shows the output spectrum of the CMOS-HOEM in the 60 GHz band. It is clearly shown that there are 60 GHz second harmonic LO signals, upper sideband (USB) at 60.1 GHz and lower sideband (LSB) signals at 59.9 GHz.

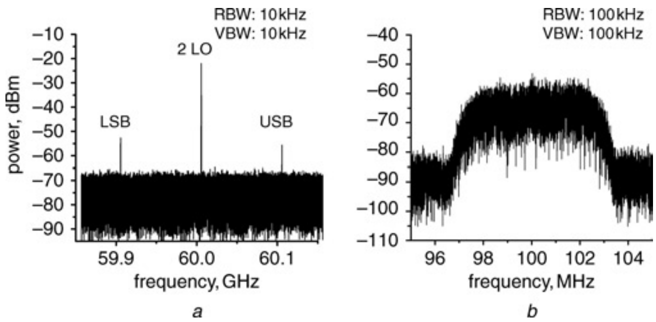

Fig. 3 *Spectra*
a Output spectrum of CMOS-HOEM when 30 GHz electrical LO and 100 MHz optical IF signal is injected into device
b Output spectrum of Schottky diode envelope detector

A 25 Mbit/s 32 QAM data signal is optically modulated using an electro-optic modulator, and then transmitted through optical fibre. At the base station, photodetection and harmonic frequency up-conversion to the 60 GHz band is performed using the CMOS-HOEM. At the mobile terminal, transmitted data together with LO signals in the 60 GHz band are boosted by a low-noise amplifier and down-converted to the IF band by a Schottky diode envelope detector. In the experiment, the 60 GHz wireless link is omitted by connecting the antenna base station and the mobile terminal with a cable. The bias voltage of 10.1 V is applied to the device since this provides the maximum avalanche gain, and the injected electrical LO power is 20 dBm. Fig. 3*b* shows the down-converted data signal spectrum at the output of the Schottky diode envelope detector. For the evaluation of link performance, the data signal in the IF band is demodulated by a vector signal analyser (VSA). Fig. 4 shows constellation and eye diagrams of the demodulated 25 Mbit/s, 32 QAM data signal at the VSA. The measured error vector magnitude (EVM) is approximately 5.1%, which corresponds to about 21.7 dB SNR.

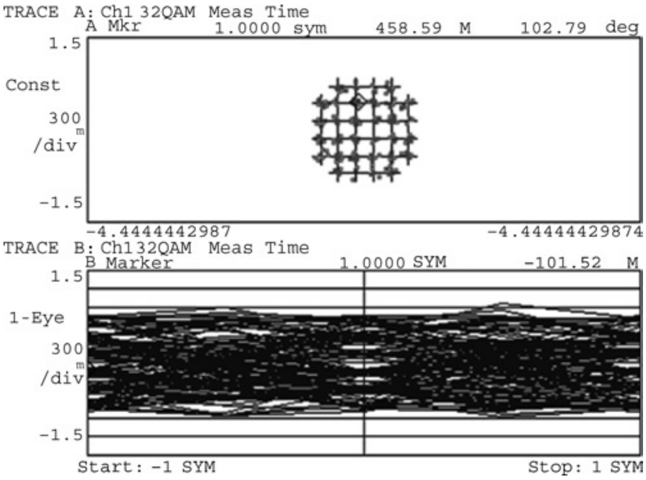

Fig. 4 *Constellation and eye diagram of demodulated 25 Mbit/s 32 QAM data signal at VSA*

These results demonstrate that CMOS-HOEM can be used in antenna base stations for low-cost fibre-supported 60 GHz self-heterodyne systems. With a sufficiently high optical power source, the distance between the central office and the antenna base station can be expected to reach a few hundred metres. In addition, high performance millimetre-wave components should provide the necessary 60 GHz link range for many wireless applications.

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