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Proposal for 60 GHz wireless transceiver for the radio over fiber system

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ABSTRACT

A 60 GHz mm-wave wireless transceiver for radio over fiber (RoF) is proposed, using sub-harmonic mixer and IF digital signal processing. This scheme can overcome LO leakage and I/Q mismatch. Moreover, an effective verification method of co-simulation between VPI and ADS platforms is considered, this gives full play to the respective advantages of them and in this way we can obtain the results. From these results of the designed wireless transceiver measured by frequency and time domain, we find that 1 Gbit/s data signals carried by 60 GHz mm-wave signals can be successfully recovered. Additionally, the isolation and the conversion loss of the mixer are more than 20 dB, less than 17 dB, respectively. Moreover, the output power of the 60 GHz transceiver is nearly linear with different input powers that are more than −30 dB m.

1. Introduction

A future access communication system must target ubiquitous broadband wireless access with large capacity, high data and low cost application. A radio over fiber (RoF) using optical fiber to achieve high bandwidth, low loss of high data rate signal for remote transmission, and the use of millimeter-wave (mm-wave) can make access rate up to Gbps. Therefore, RoF has been considered as a potential candidate for supporting future broadband access networks [1, 2]. The transmitter and receiver of 60 GHz mm-wave RoF system is an important part of the broadband access system [3]. And many existing schemes of 60 GHz transceiver have been reported. For example, a single channel imaging receiver is composed of an imaging lens and a small photo-sensitive area photodiode attached on a 2-axis actuator for optical wireless access communication [4], mm-wave power amplifier (PA) with reliability considerations is for hot carrier injection degradation [5], 60 GHz phased-array transceiver pair implemented in 65 nm standard digital CMOS and packaged with an embedded antenna array has also been studied [6], zero-intermediate frequency (IF) receiver or the twice mixer receiver in 65 nm CMOS was found in [7], and another schemes have been also considered, such as two-RF-port electro-absorption transceiver in 60 GHz RoF system [8], 60 GHz multi-gigabit CMOS transceivers for In-building HD and data [9], and multi-service 60 GHz mm-wave RoF inter-operable with multi-gigabit wireless transceiver [10]. However, in those schemes, 60 GHz mm-wave signals which are received by the wireless transceiver are down-converted to analog baseband signals by zero-IF mixer or two mixers and so on. They divide 60 GHz mm-wave signals into two branches, and then mix them with two orthogonal LOs (local oscillators) source respectively. In addition, those schemes-based systems have some shortcomings such as I/Q mismatch and local-oscillation (LO) leakage [11–13] in order to get two orthogonal baseband signals due to the analog frequency conversion. So LO leakage and I/Q mismatch are in the existing schemes of 60 GHz transceiver.

In this paper, we give a novel transceiver scheme for the 60 GHz RoF system. Moreover, we make use of the co-simulation of VPI which is an optical simulate platform and ADS (advanced design system) which is a RF circuit simulate platform. We use the ADS platform to design specific 60 GHz mm-wave mixer, then join the mixer to the VPI platform to finish the whole 60 GHz mm-wave RoF system demonstration.

2. Principle of the proposed 60 Ghz transceiver

The principle of 60 GHz mm-wave transceiver for RoF is shown in Fig. 1. In this scheme, an antenna receives the mm-wave signals whose center frequency is 60 GHz and carries data signals from a base station (BS). The received mm-wave signals pass through a circulator to the receiver. In the receiver, firstly, the down-link signal pass a pre-selection filter to remove the noise from the

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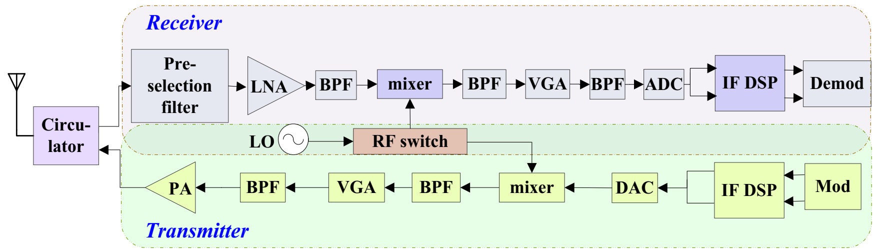

Fig. 1. The proposed schematic of the 60 GHz mm-wave transceiver for the RoF system.

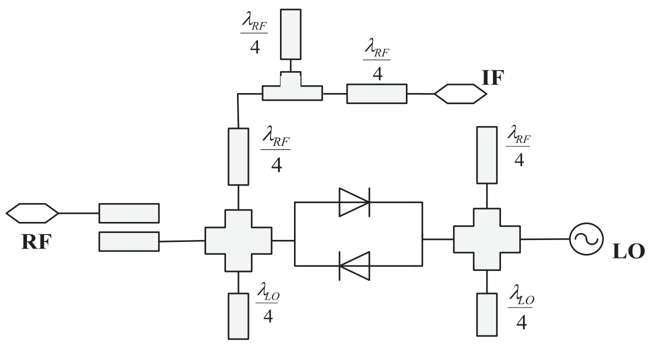

Fig. 2. The schematic of 60 GHz mm-wave harmonic mixer module.

wireless channel, then through a low noise amplifier (LNA) to amplify the received signals and a band-pass filter to remove the noise from amplification. Secondly, the 60 GHz mm-wave signals are down-converted to IF analog signals in the designed mixer. The LO source is used for frequency down-convert or up-convert respect to receiver and transmitter. After a band-pass filter to filer the noise, a variable gain amplifier (VGA) to gain the power of the IF signals, and a band-pass filter to filter the noise from amplifier, we make the IF analog signals to be IF digital signals by the analog to digital converter (ADC). Then with the IF digital signal processing, we get two orthogonal signals. With the demodulation, the baseband data signals are recovered. As shown in Fig. 1, the transmission of wireless terminal transceiver is just reversed. The signals are up-linked to the BS by the transmitter. Firstly, we modulate the data signals to get two orthogonal digital signals. Then with IF digital signal processing, we obtain IF digital signals. After the digital to analog converter (DAC), the IF signals mix with LO selected by the RF switch to get 60 GHz mm-wave signals. Through the VGA, BPF and power amplifier (PA), the 60 GHz mm-wave signals are transmitted by the antenna.

We use sub-harmonic mixer based on Schottky diode to solve the problem of LO signal leakage to RF port. The 60 GHz harmonic mixer is considered as shown in Fig. 2. And it is consisted of microstrip lines and two Schottky diodes. The GaAs flip chip used is MS8251 from Microsemi Corporation. The laminates used are RT/duroid 5880 from Rogers Corporation. And the microstrip line of $\lambda_0/4$ could prevent the frequency match to λ_0 passing to other ports and offer loop to its own port [14].

We can find that the frequency of LO source is only half of the frequency of the received RF signal, so it reduces the cost. In this scheme, the center frequency of mm-wave signals is 60 GHz carrying the 1 Gbit/s signal, and the frequency of LO source is 29.25 GHz, then due to $\omega_{IF} = \omega_{RF} - 2\omega_{LO}$, we can get the center frequency of IF analog signal is 1.5 GHz.

Additionally, we adopt the IF digital signal processing to overcome the problem of I/Q mismatch in the existing scheme due to the analog frequency conversion, as shown in Fig. 3. The IF DSP is digital IF down-converter base on poly-phase filter [15]. After ADC, the analog signals are converted to IF digital signals. Then, after

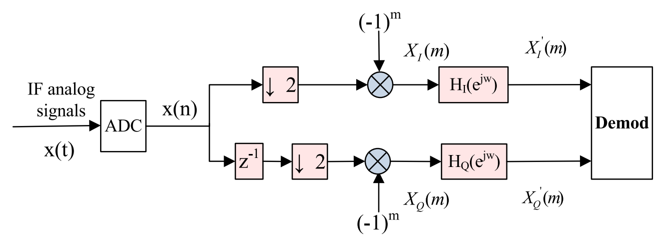

Fig. 3. The schematic of IF DSP module.

parity extraction, sign adjustment, and filtering, the IF digital signals are down-converted to two orthogonal baseband signals. It could avoid the impact of the amplitude and phase mismatch between the in-phase and the orthogonal branches for the analog demodulator using two multipliers.

3. System demonstration and results

The simulation system frame in VPI is shown in Fig. 4. In the first branch, 1 Gbit/s NRZ signals is modulated on an optical carrier, and coupled with another optical signal. After optical fiber, we then get the desired mm-wave carrier whose center frequency is 60 GHz in a photodetector (PD). After a band pass filter, an amplifier with 33 dB gain and ADS-Interface module, the 60 GHz mm-wave signal is sent to the designed 60 GHz mm-wave mixer module in ADS platform, and get output IF signal with 1.5 GHz center frequency, then back to VPI, continue the IF pass filter, finally get the IF analog signals with 2 GHz bandwidth. So after the mixer, the data file is transmitted back to VPI to continue to complete the follow-up link simulation. The obtained results are shown in Figs. 5–8.

Fig. 5(a)–(d) shows the spectra and waveforms of time domain at nodes (a)–(d) of Fig. 4, respectively. The baseband signal, 60 GHz signals after the PD, the 60 GHz signals after the BPF and the amplifier, and the IF signals with the central frequency at 1.5 GHz after the mixer and the BPF. From these results, we can see that the 60 GHz mm-wave signals after the PD is properly down-converted to the IF signal with center frequency at 1.5 GHz by the mixer. And the corresponding waveforms in time domain at nodes (a)–(d) have also been obtained.

Fig. 6(a) shows the input IF signal of ADC. The bit rate of baseband signal from central station is 1 Gbit/s. After optical modulation, the bandwidth of the useful signal is 2 GHz. So through the mixer, we get IF output signal with the center frequency at 1.5 GHz, and the bandwidth of the signal is 2 GHz. But the IF signal within half a sideband carries the complete useful signal, so the useful baseband signal could be recovered by the IF signal with the center frequency at 2 GHz, and the bandwidth is 1 GHz, as shown in Fig. 6(a). Through the ADC with the 8/3 GHz sampling frequency, the analog signal is converted to digital signal. Then through parity extraction, digital signal spectrum is doubling and shifted, we get the spectrum as shown in Fig. 6(b). The original signal could be recovered by the baseband signal of 0–2 GHz.