Multiple-frequency basestation RoF system based on polarization multiplexed FWM in SOA*

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An approach of multiple-frequency millimeter-wave (mm-wave) signal generation is proposed for radio-over-fiber (RoF) system with multiple-frequency basestations (MFBSs). Two groups of orthogonally polarized signals are injected into a semiconductor optical amplifier (SOA), and subsequently ten new different wavelengths are generated via four-wave mixing (FWM) effect. At each MFBS, different wavelengths are filtered out using demultiplexer and then input to a photodiode (PD) to generate the mm-wave signals with the frequencies from 52 GHz to 68 GHz at the interval of 2 GHz. Simulation results verify that the proposed multiple-frequency generation for MFBS RoF system can work properly.

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As one of the key technologies of radio-over-fiber (RoF) system, millimeter-wave (mm-wave) generation has attracted extensive attention[1-4] recently. Many techniques related to the generation of mm-wave signals in RoF system have been reported, such as optical external modulation technique and dual-wavelength optical modulation technique[5-10]. But these methods are mainly used to generate a single frequency mm-wave which is not efficient for the higher demand of various services in RoF system. Ref.[11] has proposed a scheme of using four-wave mixing (FWM) effect in semiconductor optical amplifier (SOA) to generate multiple-frequency mm-wave for achieving multiple-basestations in RoF system. However, this scheme can only generate three different mm-waves, and it couldn't effectively meet the demands of wireless access with high bandwidth and multiple services. Besides, Refs.[12-18] also reported different schemes for multiple-frequency basestation (MFBS) RoF systems. Herein, we put forward the polarization multiplexed FWM effect in SOA to generate nine different mm-waves with frequencies near 60 GHz from 52 GHz to 68 GHz at the interval of 2 GHz.

The structure of our proposed MFBS-RoF system is shown in Fig.1. The system has good scalability and flexibility, which can effectively meet the practical application needs of remote user.

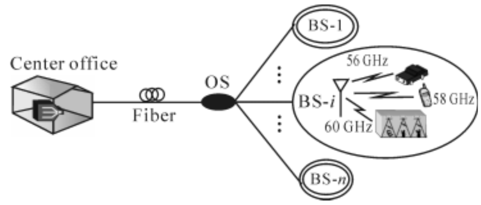

Fig.1 Structure of MFBS-RoF system

Fig.2 shows the fundamental principle of our proposed polarization multiplexed FWM effect in SOA in the central station (CS). The input optical signal before SOA is shown in Fig.2(a). There are one pump band and two signal bands in y polarization (pol-y) with 2 GHz grid between them. While in x polarization (pol-x) there are two pump bands with 60 GHz grid. As shown in Fig.2(a), pump1, pump2 and pump3 have 30 GHz interval between them. Then the input signals are sent into SOA to perform FWM effect, and the output signals are shown in Fig.2(b). In pol-x, eight new signal bands are generated near pump2 and pump3, respectively. The frequency interval between the new signal bands and the pump signal are all 2 GHz for both pump2 and pump3. Meanwhile, there are two new signal bands generated on the

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left side of pump1 in pol-y. A polarization beam splitter (PBS) is utilized to separate the output signal into two different polarization states and the signal in pol-x is shown in Fig.2(c). Consequently, signal in pol-x is used to generate multiple mm-wave signals near 60 GHz for the use of MFBS in RoF system to support high bandwidth and multiple services.

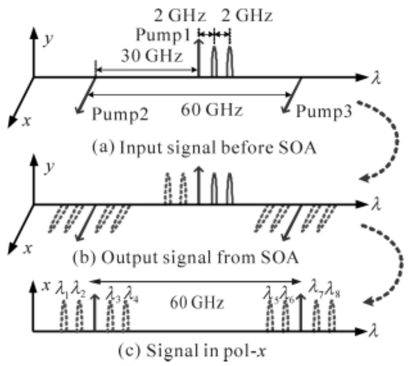


Fig.2 Principle of the proposed MFBS-RoF system

Fig.3 shows the simulation setup of the proposed MFBS-RoF system via VPI Transmission Maker (version 8.3). In the CS, laser-diode (LD-1) with the central frequency of 193.1 THz is used as the optical source and it is modulated in Mach-Zehnder modulator (MZM-1) by a 30 GHz radio frequency (RF) source to perform optical double-sideband (ODSB) modulation. Two generated sidebands are pump2 at 193.07 THz and pump3 at 193.13 THz, respectively. Then a polarization controller (PC-1) is used to adjust the polarization state of two pump signals to pol-x. Meantime, LD-2 at 193.03 THz is modulated in MZM-2 by a 2 GHz RF source to perform anther ODSB modulation, and thus two pump bands at 193.12 THz and 139.14 THz are got, respectively. The two pumps are combined with LD-3 at 193.1 THz, and then the

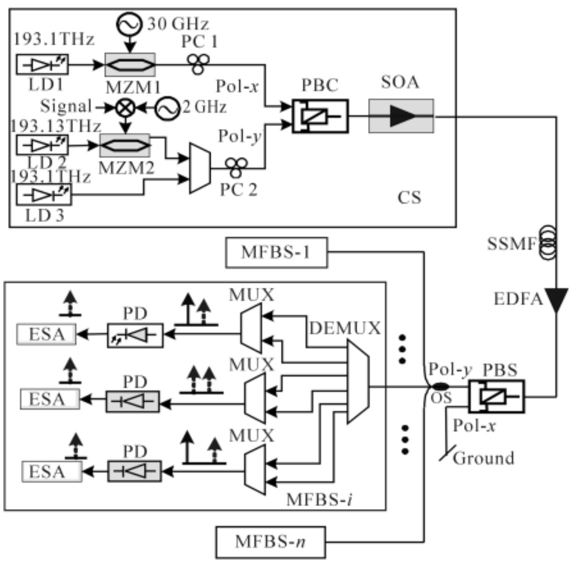


Fig.3 Simulation setup of the proposed MFBS- RoF system

combined signal is sent into PC-2 to adjust its polarization state to pol-y. After that, a polarization beam combiner (PBC) is adopted to generate polarization multiplexed signal by combing the signals in pol-x and pol-y together. The polarization multiplexed signal is taken as the input of SOA to perform FWM effect. Finally, ten new wavelengths are generated, and eight of them are generated in pol-x.

All output signals of SOA are transmitted over standard single-mode fiber (SSMF), and then enter the remote node (RN), where a PBS is used to obtain the signal in pol-x. The pol-x signals from the PBS are divided into different branches for every MFBS using an optical splitter (OS), and different frequencies of the received signal are separated by a demultiplexer (DEMUX) at the MFBS. At each MFBS, according to the need of end users, two of the received signal bands are chosen and sent into a PD to generate mm-wave with a particular frequency by the optical heterodyning of two selected frequency bands. In this scheme, there are ten different frequency bands, so we can obtain nine different mm-waves from 52 GHz to 68 GHz with the frequency interval of 2 GHz. For example, if MFBS-i needs 52 GHz, 62 GHz, 68 GHz mm-waves, we can get them by selecting [λ_1, λ_5], [λ_2,λ_5] and [λ_1,λ_8] to take optical heterodyning in PD. In consequence, this scheme can support MFBSs with multiple mm-waves near 60 GHz for the communication of high bandwidth and various services in RoF system.

The main parameters of our simulation setup are given in Tab.1.

Tab.1 Main parameters of the simulation setup

Simulation parameter	Simulation data
Bit rate	2.5×10^9 bit/s
Sampling rate	160×10^9 Hz
Laser output power	1 mW
Extinction ratio of MZM	30 dB
Half-wave voltage of MZM	5 V
SOA injection current	0.45 A
Fiber length	20 km
Fiber attenuation coefficient	0.2×10^{-3} dB/m
Fiber dispersion coefficient	16×10^{-6} s/m^2
Dispersion slope	0.08×10^3 s/m^3
Nonlinear coefficient	2.6×10^{-20} m^2/W

The spectrum of SOA input signal is shown in Fig.4. Pump1 and two signal bands on the right are in pol-y, while pump2 and pump3 are in pol-x. Three pump signals have 30 GHz frequency interval and the frequency interval between pump2 and pump3 is 60 GHz. Pump1 and two signal bands have 2 GHz interval. The power levels of three pumps are about -5 dBm and the power levels of two signal bands are about -18 dBm. The injection current of SOA is set at 0.45 A to achieve a better performance of FWM effect. The spectrum of SOA output signal is shown in Fig.5. We can find that ten new wavelengths are generated and eight of them are in pol-*x*, which are λ_1–λ_8. The spectrum of signal in pol-*x* is shown in Fig.6. The frequency interval between pump2 and pump3 is 60 GHz. The frequency grid of five frequency bands of λ_1 to λ_4 and pump2 is 2 GHz, and the frequency grid of λ_5 to λ_8 and pump3 is 2 GHz, too. Fig.7 shows the electric spectrum of nine different mm-waves after optical heterodyning in PD, and the frequency grid of them is 2 GHz.

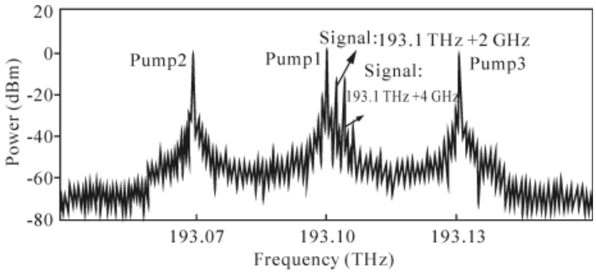


Fig.4 Optical spectrum of SOA input signal

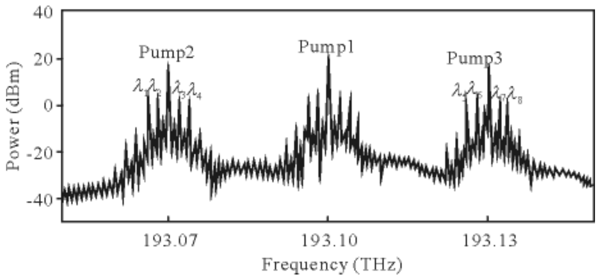


Fig.5 Optical spectrum of SOA output signal

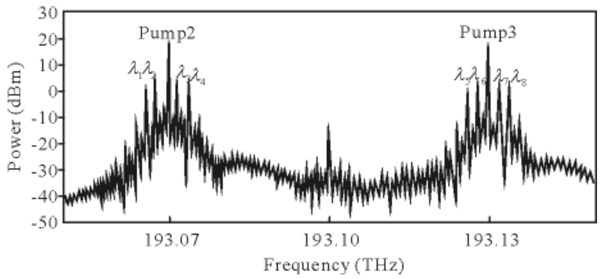


Fig.6 Optical spectrum of SOA output signal in pol-*x*

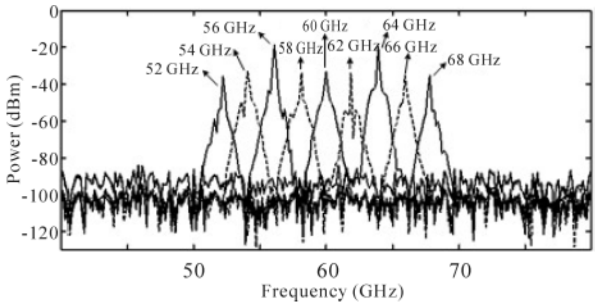
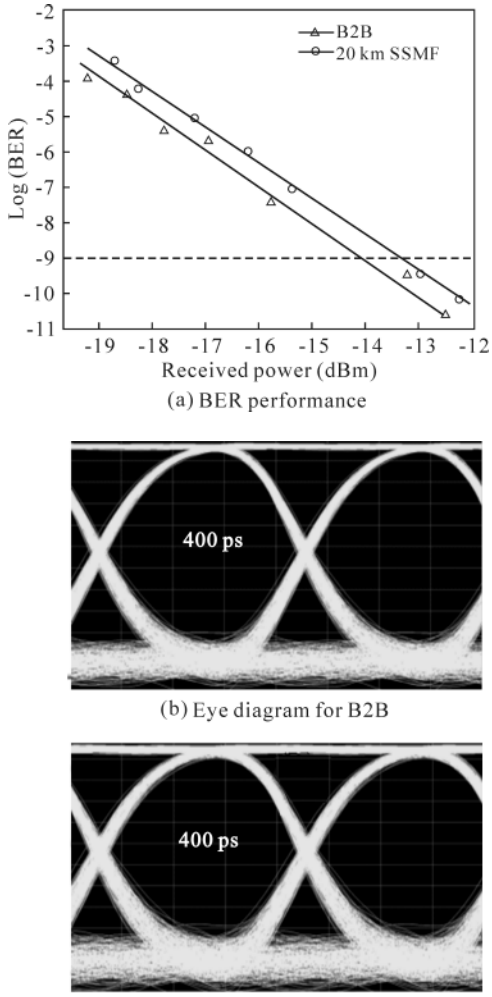


Fig.7 Electrical spectra of generated mm-waves near 60 GHz

The bit-error-rate (BER) performance and eye diagrams of the proposed MFBS-RoF system for both back-to-back (B2B) and 20 km SSMF transmission are shown in Fig.8. BER performance of 10^{-9} is also plotted for reference. For B2B case, received power of about -14 dBm is required to reach BER of 10^{-9}. For 20 km SSMF case, the received power to reach BER of 10^{-9} is about -13 dBm. So the power penalty after 20 km SSMF transmission compared with B2B is about 1 dBm. Corresponding eye diagrams at the BER of 10^{-9} for B2B and 20 km SSMF are shown in Fig.8(b) and (c).



(a) BER performance

(b) Eye diagram for B2B

(c) Eye diagram for 20 km SSMF transmission

Fig.8 BER performance and eye diagrams of the proposed MFBS-RoF system

An MFBS RoF system is proposed and successfully demonstrated by utilizing the polarization multiplexed FWM effect in SOA to generate multiple mm-waves near 60 GHz. Simulation results effectively prove the rationality and feasibility of our proposed MFBS-RoF system. By selecting two frequency bands from SOA output signal to take optical heterodyning in each MFBS, we can obtain nine different mm-waves from 52 GHz to 68 GHz with 2 GHz grid, which can help to configure each BS with multiple frequency mm-waves in the RoF system. Consequently, this proposal could meet the requirements of the remote users with high bandwidth and various services, and it is a promising candidate for next-generation broadband wireless access networks.

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