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Wireless and Wireline Data Distribution Using Single Local Oscillator on a Multi-Band Radio-over-Fiber System

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Abstract
In this work, we propose a multi-band signals generation technique with frequency doubled millimeter wave signal using a single local oscillator (LO) on a bidirectional Radio-over-Fiber (RoF) system. At central office (CO), a radio frequency (RF) LO signal with a phase modulator (PM) is used to generate multi-band signals. First, LO signal is modulated by downlink data signal, which is then used to modulate optical carrier for downlink transmission with the help of PM. After the transmission through a 40 km single mode fiber (SMF), received optical signal at base station (BS) is used to generate, frequency doubled 42 GHz millimeter wave (MMW) signal, 21 GHz microwave (MW) signal and a baseband (BB) signal. Downlink optical carrier is filtered and reused for uplink data distribution to support bidirectional transmission. An error-free transmission of 2.75 Gb/s data for a SMF of 40 km length, is achieved for both downlink and uplink transmission. Electrical and optical domain representations are shown at different points and the variations in min. log of BER are plotted against received optical power (ROP).

Keywords- Radio-over-Fiber; multi-band signals; single local oscillator; frequency doubled millimeter wave signal; single phase modulator; wireless and wired distribution; hybrid networks.

1. Introduction

Demand of high data rate services for both wireless and wireline distribution is increasing day by day. RoF technology uses wide optical spectrum and can be a possible solution to this increasing bandwidth demand problem. Fig.1, shows a basic RoF system configuration [15]. A bidirectional RoF system enables high data rate signals' distribution as well as provides a full-duplex communication among end users [1]-[2]. In addition, millimeter wave technology provides wide bandwidth for the distribution of wireless multi-gigabit services [3]-[5]. Furthermore, hybrid access networks (HAN) integrate different networks at single platform [6]-[8]. Multi-band signals generation techniques allows the distribution of high data rate signals in different frequency bands to support different wireless and wireline applications simultaneously [12]-[14]. In [12], multi-band signals are generated using heterodyne mixing technique with high scalability. Ref. [13], used multi-band signals for in-building data distribution. In ref. [14], dual-parallel mach zehnder modulator (MZM) and a following single drive (MZM) is used to generate multi-band signals through optical carrier suppression and frequency shifting techniques.

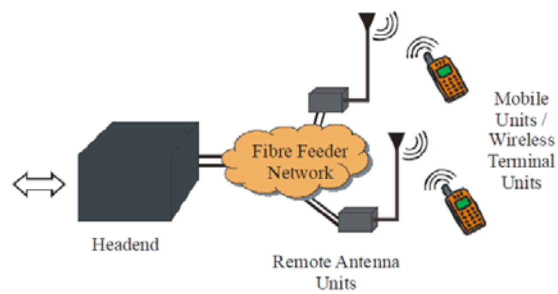

Fig.1: Radio over Fiber system concept

Here, a multi-band signals generation technique with frequency doubled millimeter wave signal using a single LO is proposed. Multi-band signals are generated using downlink signal of a bidirectional RoF system. At CO, LO signal is modulated with 2.75 Gb/s downstream data. A PM is then used to modulate optical carrier according to the input electrical signal. Generated optical signal is transmitted through a 40 km SMF and is used to generate 42 GHz MMW, 21 GHz MW and a BB signal, at BS. MMW and MW signals are further used for wireless distribution from BS to mobile unit (MU). For bidirectional transmission, similar 2.75 Gb/s upstream data is used to transmit from BS to CO by filtering and reusing the downlink optical carrier. Therefore, the need of an additional light source and wavelength management at the BS is eliminated. This scheme efficiently generates frequency doubled 42 GHz MMW, 21 GHz MW signal and BB signal, with a single 21 GHz LO signal.

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2. Principle of Operation

Fig.2 shows the schematic diagram of multi-band signals generation technique. Here, first downstream data is used to modulate an RF carrier (RF1). RF modulated signal is then applied to PM to modulate optical carrier (frequency= fo) generated by a CW laser. This modulation generates two sidebands on both sides of optical carrier in optical domain. As the frequency of optical carrier is fo, the frequencies of generated sidebands become fo±RF1. Generated optical signal is then amplified using erbium doped fiber amplifier (EDFA) and transmitted from CO to BS through a SMF. Optical signal is received at BS and split into three signals using optical power splitter. First signal is used to generate frequency doubled signal by filtering fo-RF1 and fo+RF1 data sub-carriers, which provides a 2*RF1 frequency separated sub-carriers in optical domain. Filtered signal is then applied to PIN diode to convert optical signal into electrical RF signal, which is further used for wireless distribution. This is a frequency doubled signal because the frequency of generated electrical signal is exactly twice that of RF signal used for modulation at CO, i.e. 2*RF1.

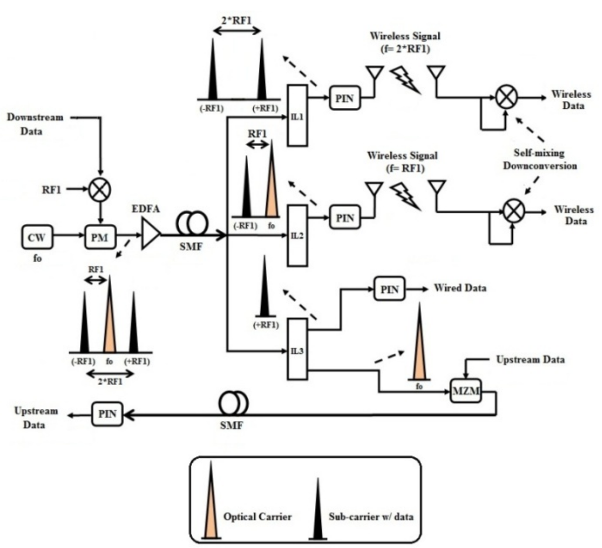

Fig.2: Schematic diagram of multi-band signals generation

At MU, wireless signal is received and down-converted using self-mixing down-conversion. Second signal is used to generate an electrical signal of frequency RF1, in which optical carrier (fo) is filtered with fo-RF1 data sub-carrier to provide RF1 frequency separation in optical domain. PIN diode is used to convert this optical signal into electrical signal of frequency RF1, this is also used for wireless distribution. The reception and down-conversion of this signal at MU is same as we discussed above. In third signal, fo+RF1 data sub-carrier and optical carrier are filtered at upper and lower port of interleaver (IL3) respectively. From upper port, data sub-carrier is used for direct detection and applied to PIN diode, which converts this signal directly into a baseband signal for wireline data distribution. Optical carrier from lower port is used to transmit uplink data and applied to a MZM with data signal. Generated optical signal is transmitted in opposite direction. The detection of uplink signal is direct detection as the received optical signal is applied to PIN diode to generate data signal.

3. System Description

The setup as shown in fig.3, is simulated using OptiSystem software. At CO, a pseudo random bit sequence (PRBS) generator with non return to zero (NRZ) pulse, is used to generate electrical 2.75 Gb/s BB signal. Generated BB signal is then used to modulate 21 GHz RF carrier (RF1). Modulated RF signal is applied to electrical input port of PM with an optical carrier at its optical input port. Optical carrier is generated by a CW laser diode operating at fo=193.1 THz. Phase modulator modulates optical carrier according to input RF signal and the modulated optical signal is obtained at the optical output port of PM, this signal contains two data sidebands on each side of optical carrier. The frequencies of these sidebands are 193.1 THz±21 GHz. Optical signal is then amplified using EDFA and distributed through a 40 km SMF.

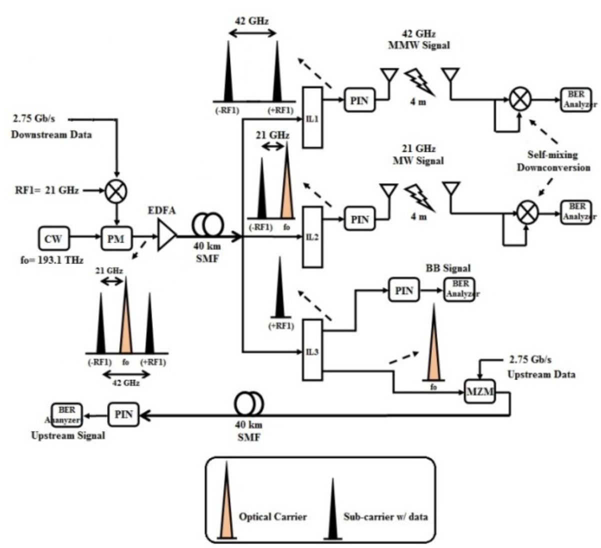

Fig.3: Simulation setup

Received optical signal is used to generate different frequency band signals by splitting in into three signals using an optical power splitter. From first signal, fo-21

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GHz and fo+21 GHz data sidebands are filtered to provide a 42 GHz optical domain separation between two sub-carriers to generate frequency doubled 42 GHz MMW signal. PIN diode is used to convert optical signal into 42 GHz RF MMW signal, which is used for wireless transmission of 4m from BS to MU. An electrical attenuator of 0.1 dB (@ 25 dB/km, for a distance of 4 m) is used to represent wireless transmission. After wireless transmission, signal is received by MU, which demodulates the signal to get original data by self mixing downconversion. Similarly, to generate 21 GHz MW signal, fo-21 GHz data sub-carrier and fo optical carrier are filtered using IL2, which gives 21 GHz optical domain separation between data sub-carrier and optical carrier. Filtered optical signal is applied to PIN diode, which converts it into RF 21 GHz MW signal for wireless distribution between BS and MU. Wireless transmission and reception of 21 GHz MW signal is similar to 42 GHz MMW signal as discussed above. Third signal is used to separate fo+21GHz data sideband and fo optical carrier with the help of IL3. From upper port, data sideband is used for BB signal direct detection, which is applied to PIN diode to convert optical signal directly into BB data signal for wired data distribution. Optical carrier from lower port is remodulated with the help of MZM for upstream transmission, which is applied to MZM with 2.75 Gb/s upstream data and generated optical signal it transmitted in reverse direction from BS to CO. At CO, direct detection of upstream signal is achieved by applying the signal to PIN diode, which converts this signal directly into BB data signal.

4. Results and Discussion

At the output of PM, we generated two sub-carriers with the RF modulated signal, as shown in fig.4. Frequency of optical carrier is fo (193.1 THz) and the frequencies of generated sub-carriers are fo±21 GHz. Sub-carriers used in this work are 1st harmonics generated by 21 GHz signal.

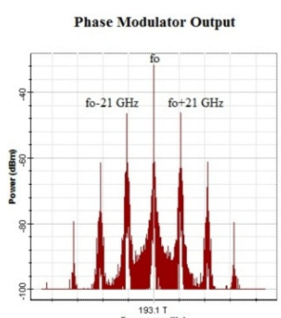
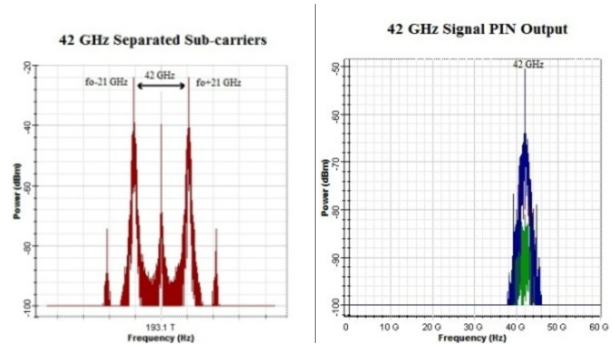
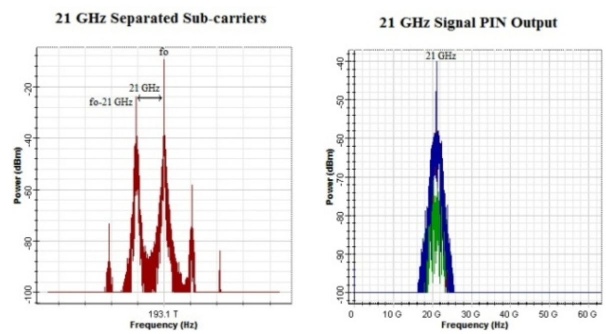


Fig.4: Phase modulator output



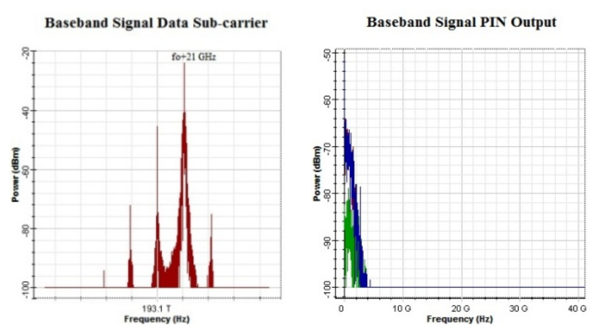
(a) (b)

Fig.5: 42 GHz signal (a) Separated sub-carriers (b) PIN output



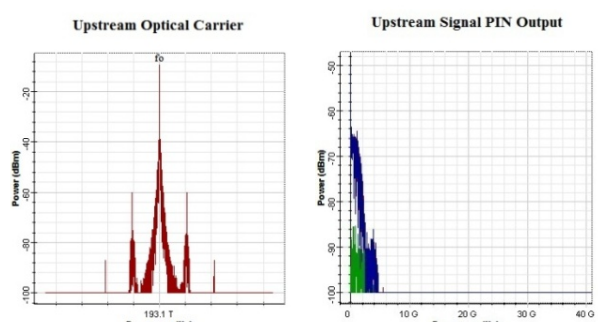
(a) (b)

Fig.6: 21 GHz signal (a) Separated sub-carriers (b) PIN output



(a) (b)

Fig.7: Baseband signal (a) Data sub-carrier (b) PIN output



(a) (b)

Fig.8: Upstream signal (a) Optical carrier (b) PIN output

Fig.5 shows the generation of frequency doubled 42 GHz MMW signal. In fig.5(a), fo-21GHz and fo+21 GHz sub-carriers are filtered to get 42 GHz separated data sub-carriers. Fig.5(b) shows PIN diode output for this optical signal. Optical signal is converted into a 42 GHz MMW RF signal, as can be seen from electrical domain of generated signal. The only frequency components available in this signal are around 42 GHz, which is a spectrum of a 42 GHz RF carrier modulated with data signal. Generation of 21 GHz MW signal is shown in fig.6. In fig. 6(a), optical carrier (fo) is filtered with fo-21 GHz sub-carrier to provide a 21 GHz optical domain separation. This filtered signal is applied to PIN diode and electrical domain representation of PIN diode output is shown in fig.6(b). To generate BB signal fo+21 GHz data sub-carrier is filtered for direct detection as shown in fig.7. Fig.7(a) shows optical spectrum of filtered data sub-carrier, which is applied to PIN diode. Output of PIN diode is shown in fig.7(b), where frequency domain representation of generated electrical signal represents the spectrum of a BB signal with lower frequency components near to zero. For uplink data transmission, optical carrier (fo) of downlink signal is filtered as shown in fig.8(a). A MZM is used to modulate this optical carrier with symmetric uplink data. At CO, upstream signal is applied to PIN diode for direct detection. Detected BB data from upstream signal is shown in fig.8(b). Variations in min. log of BER values against received optical power (ROP) are shown in fig.9. From fig.9, it can be observed that the values of min. BER for 21 GHz signal are better than that of other signals.

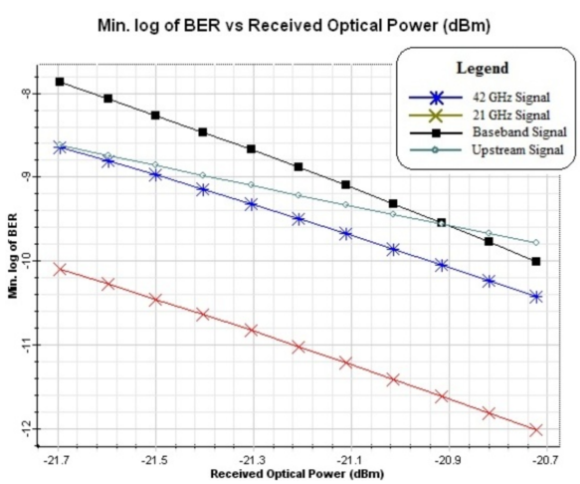


Fig.9: Min. log of BER vs Received optical power

5. Conclusion

A multi-band signals generation technique with frequency doubled millimeter wave signal using a single LO is proposed. In this method, different frequency band signals are generated using a single RF local oscillator (LO) at CO to support both wireless and wireline services. At BS, three different signals are generated; including frequency doubled 42 GHz MMW signal, 21 GHz MW signal and BB signal and symmetric uplink data is transmitted by reusing downlink optical carrier. Investigations revels that the distribution of these multi-band signals with bidirectional transmission in a single configuration provides high performance, mobility and management stability. Transmission of 2.75 Gb/s data in both downlink and uplink direction for all the generated signals through 40 km SMF is successfully achieved. Results show that this configuration has a potential to feed different wireless and wired applications in different frequency bands with high data rate signals to support future optical-wireless integrated networks.

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