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82 GHz Millimeter-Wave Transmission Over OFDM ROF System

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Abstract: ***Orthogonal Frequency Division Multiplexing (OFDM) based signal transmission over Millimeter-Wave Radio-over-Fiber (mm-Wave RoF) systems is proposed. For that an external modulator and an optical interleaver are used to generate dual octupling-frequency optical millimeter waves. Simultaneously. The frequency of local oscillator signal is reduced largely due to frequency octupling. OFDM signal is used as the downlink data for transmission. Most of the advanced systems are using OFDM based signal such as LTE 4G or WiMAX network. So a system that uses RoF technology to transmit OFDM signal by mm-Wave will be effective. In this proposal, the advanced technologies are combined in order to get an effective model to transmit data at higher speed with a reasonable price.***

Index terms: ***Orthogonal frequency division multiplexing, Radio over fiber (RoF), Millimeter-wave, wavelegth reuse.***

I. INTRODUCTION

Nowadays, due to the development of new services that require higher bit-rate such as video conference, video on demand etc., the network providers have to upgrade their net- works to higher speed. At the same time, due to the increasing competitive pressure, the price of telecommunication services needs to be reduced. So,the problem is finding a technology that can transmit high bit-rate data at a rather low cost. For a system that is able to transmit very high speed data, a system using high frequency maybe a good choice. However, frequency spectrum is very precious. Transmission of signals at extremely high frequencies faces many challenges such as high attenuation. In addition, when using mm-Wave for signal transmission, the size of radio cell is very small leading to increase in the number of base stations (BS) sharply. In this case, the structure of BS requires to be simple, small and cheap. Those requirements make us think of RoF technology because this technology has simple BS structure and low cost. Besides, OFDM signal is gaining popularity day by day. Most of the advanced systems such as LTE 4G or WiMAX network use OFDM based signal. So, it is interesting to analyze a system that uses RoF technology to transmit OFDM signal by mm-Wave [1],[2].

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In this paper, the work of [3] is modified by using continous wave laser diode and Lithium Neobite Mach-Zehnder modulator (LNMZM) to generate millimeter waves (MMW) [4]. With the opening of the 71 to 76 GHz and the 81 to 86 GHz [5],[6], Bands range of millimeter wave (MMW) frequencies offers tremendous, uninterrupted bandwidth to enable wireless data transmission at speeds and capacities on par with the best fiber optic communication systems. So by frequency octupling with local oscillator frequency of 10.25 GHz millimeter waves are generated. As OFDM uses the spectrum more efficiently by allowing overlaping it eliminates inter-symbol interference (ISI) and inter-frame interference (IFI). Its performance can be improved using several techniques. The IL and turbo codes are two such techniques that improve the performance by combating with interference caused ISI among mm-wave OFDM signals [7]. A motivation for the use of quadrature amplitude modulation comes from the fact that a straight amplitude modulated signal, i.e. double sideband even with a suppressed carrier occupies twice the bandwidth of the modulating signal. This causes a huge wastage of the available frequency spectrum. QAM restores the balance by placing two independent double sideband suppressed carrier signals in the same spectrum as one ordinary double sideband suppressed carrier signal. So 4 QAM-OFDM signal is generated and used in the downlink as well as uplink while using frequency reuse [8]. This paper is organized as follows. Section II briefly presents the ROF and OFDM system. In section III, the design of the system is presented. Simulation results and discussions are addressed in section IV. Finally, conclusions are drawn in section V.

II. ROF AND OFDM SYSTEM

A. Radio over Fiber (RoF)

RoF refers to the merging of radio frequency (RF) technology for wireless and optical fiber technology for wired
transmission. It shows many advantages such as low cost, low power consumption, large bandwidth, high transmission performance, and so on [1],[13]. The advantage of this system may be a great support in the upcoming wireless network system such as mobile generations. [8],[9],[10]. As shown in Fig. 1., a typical RoF system consists of a CO, optical fiber network, remote passive node, and a large number of base stations (BSs). ROF systems performs switching, multiplexing, signal generation and processing at the CO. An optical fiber network delivers the radio signals to multiple remote nodes (RN) and then to antenna BSs and end users.

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The typical distances between the CO and the BSs are 10-25 km. The main advantage of ROF systems is the super broadband services provision with high flexibility.

The capacity of millimter-wave fiber systems can be signif- icantly increased integrating with WDM-PON systems [13]. Each wavelength can carry one millimeter-wave channel, and it is optically routed at the RN. The use of optical fiber to distribute RF signals to the BSs also offer better coverage and higher transmission performance because of low loss and immunity to electromagnetic interference of fiber.

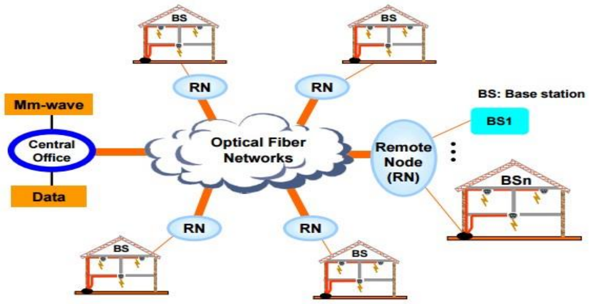


Fig. 1. ROF

In millimeter-wave fiber systems, because of high atten- uation of millimeter-wave signals in the air, numerous an- tenna BSs are needed. To make it economically viable, the BS architecture has to be simplified, consolidated, and cost effective. Therefore, it is critical for ROF systems to shift the complexity away from the RN and BS toward the CO, where the number of expensive millimeter-wave signal processing elements can be reduced greatly by sharing among multiple end users. Consolidating most of the expensive components at the CO also enables simple architecture, easier installation, and low-cost operation and maintenance. Processing centralization at the CO also provides a number of system performance ad- vantages like the feasibility of implementing efficient multiple input multiple output (MIMO) techniques and smart antennas array, centralized control of media access layer, and radio sources management. The BS only needs to perform opto-electronic conversion, amplification and broadcast functions. In this context, Microwave Photonics technologies are used to optically process millimeter-wave signals based on opto- electronic devices and all kinds of nonlinear effects.

B. *Orthogonal Frequency Division Multiplexing (OFDM)*

OFDM plays a significant role in the modern telecom- munications systems. The fundamental principle of OFDM was proposed by Chang as a technique to overlap multiple channel spectra within limited bandwidth without interfer- ence, taking consideration of the effects of both filter and channel characteristics. OFDM is a special class of multi- carrier modulation (MCM) ,that uses orthogonality between the individual subcarriers for transmission. Here a single data stream is transmitted over a number of lower rate subcarriers.

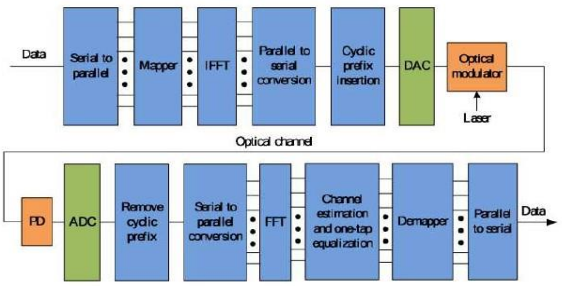
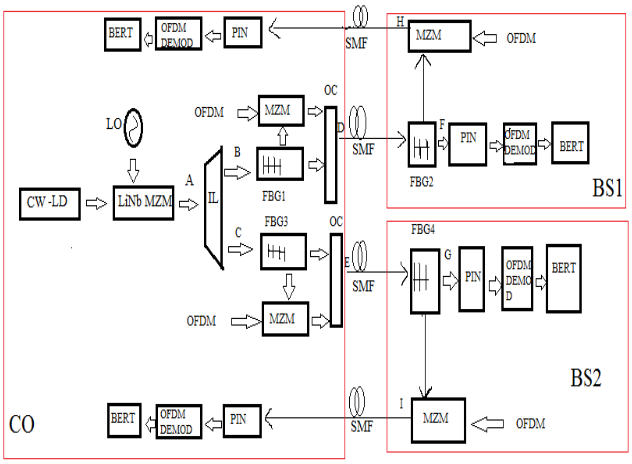


Fig. 2. Block diagram of OFDM transmitter and receiver

The main reason to use OFDM is to increase the robustness against the selective fading or narrowband interference. In single carrier system if signal gets faded or interfered then entire link gets failed whereas in multicarrier system only a small percentage of the subcarriers will be affected.

III. SYSTEM DESIGN

Fig. 3 shows the block diagram of the proposed system. A low-cost and simple full-duplex RoF system using an external modulator and an optical interleaver is used to generate dual octupling-frequency optical millimeter waves for carrying two downlink data for two base stations and wavelength reuse for uplink connection is possible [1],[9],[10],[12]. The bit rates of this system both for downlink and uplink data transmission are as high as 5 Gb/s. The 82 GHz W-band frequency for multi-gigabit capacity wireless access is generated by octupling-frequency using a 10.25 GHz RF signal.



CW-LD: continuous wave laser diode; LiNb-MZM: Lithium Niobate Mach-Zehnder modulator; LO: local oscillator; FBG: fiber Bragg grating; SMF: singlemode fiber; IM: intensity modulator; OC: optical couple PIN: pin photodiode,BERT: BER tester;LPBF: low passband filter; EDFA: erbium-doped fiber amplifier.

Fig.3. Block diagram of the system

As shown in Fig 3, a continuous-wave (CW) lightwave of frequency 193.1 THz is generated by a CW laser. This light wave is intensity-modulated via a LiNb Mach-Zehnder modulator (MZM), which is driven by a local oscillator of frequency 10.25 GHz.

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The direct current (DC) bias voltage V_{b1} or V_{b2} is adjusted to suppress the odd-order or even-order optical sidebands. The mm-wave signal generated has the first, the third and the fifth-order sidebands only the optical inter-leaver with 20 GHz frequency space and 193.051 THz starter is used to separate dual octupling-frequency optical mm-waves. After a long-distance SMF-28 fiber, the signal reaches the receiver portion. In the receiver of BS1, a FBG is used to separate the negative first-order sideband of (w_0-w_{LO}), where w_{LO} is the local oscillator frequency and w_0 is the generated frequency of CW laser, which is reused for uplink connection. The negative fifth-order sideband (w_0-5w_{LO}) and third-order sideband of (w_0+3w_{LO})are detected by a photodiode and converted into an electrical mm-wave with 82 GHz frequency. The electrical mm-wave is then amplified and finally broadcasted via the antenna if the wireless connection is needed. The negative first-order side-band of (w_0-w_{LO}) from the FBG is amplified by an EDFA and modulated by an external intensity modulator which is driven with a 4 QAM-OFDM signal.

OFDM signal is generated as shown in the Fig. 2. Here a QAM signal is orthogonally multiplexed. In an M QAM- OFDM external modulation circuit, the random bit sequence generated by the pseudo random binary sequence (PRBS) generator is fed into the M-QAM generator to produce M- Array sequences, with I and Q outputs. Next, I and Q outputs are fed into an OFDM modulator to transmit the QAM symbols over parallel overlapped orthogonal subcarriers. Then a quadrature modulator is used to modulate its I and Q electrical inputs by RF carriers of 7.5 GHz. This generated OFDM signal is then used in the proposed system.

IV. ROF SIMULATION AND RESULTS

The system was simulated using Optisystem 14 software. Fig. 4(a) depicts the output of the interleaver where the six sidebands are shown. Fig. 4(b) and (c) shows the output of the interleaver where the sidebands are separated for respective base station 1 and base station 2. Fig. 5(a) shows the output of the optical coupler at base station 1 where the sideband centered at 193.13 THz modulated, along with the other side bands. Fig. 5(b) shows the constellation diagram of 4 QAM OFDM obtained at the receiver after the downlink transmission of base station 1. Fig. 5(e) shows OFDM modulated sideband which is reused for the uplink connection. Its constellation diagram is shown in Fig. 5.(d). Similarly fig. 6(a) and (b) shows the RF signal in frequency domain after the PIN in BS1 and BS2.

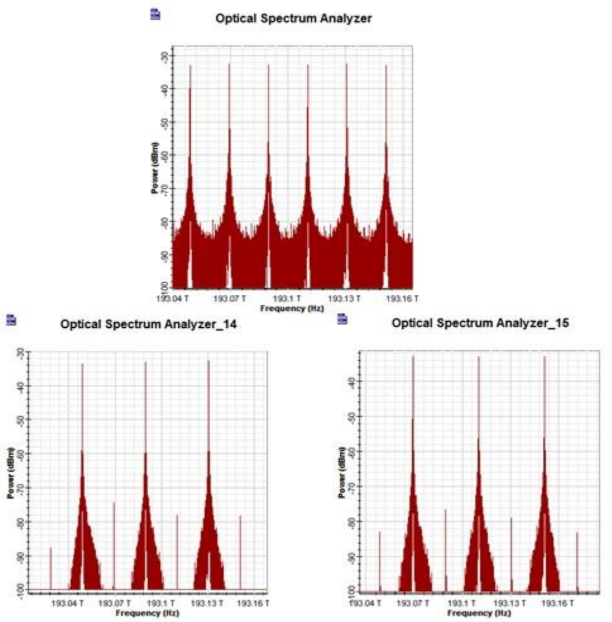

Fig. 4. (a) Output of LiNb MZM (b) Output of interleaver (1st arm) (c) Output of interleaver (2nd arm)

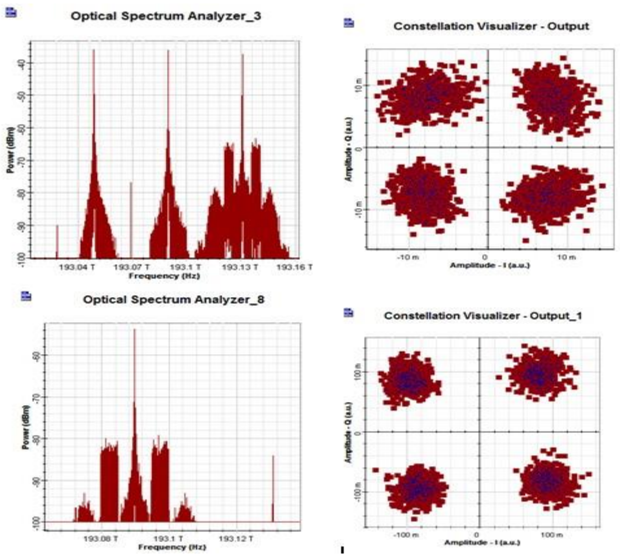

Fig. 5. (a)Output of optical coupler at base station 1 (b)Constellation diagram of downlink at BS1 (c) Modulated output at BS1 (d)Constellation diagram of uplink at BS1

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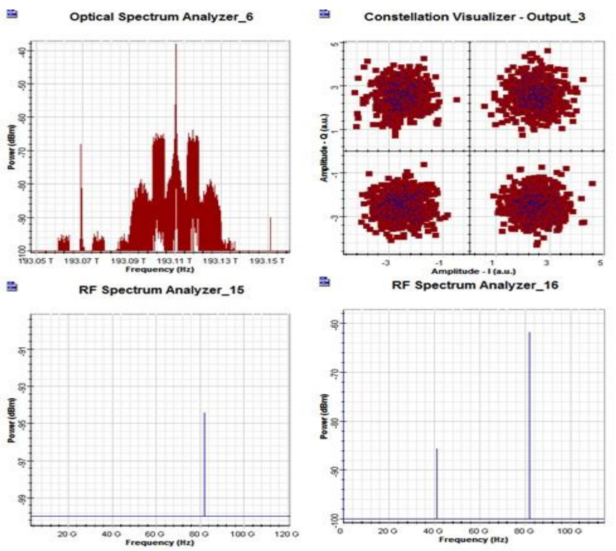

Fig. 6. (a)Modulated output at BS2 (b) Constellation diagram of uplink at BS1 (c)82GHz obtained at BS1 (d)82GHz obtained at BS2

V. CONCLUSION

A simple and cost-efficient full-duplex RoF system is implemented, in which dual octupling-frequency optical mm-waves for carrying two downlink data for two BSs and wavelengths reuse for uplink connection are generated by using an external modulator and an optical interleaver. 4 QAM-OFDM signal was used as the input in both downlink and uplink. Constellation diagrams for transmission through a 60km long fibre link for the downlink and uplink of a base station were plotted. The generated 82 GHz mm-wave was obtained at both the base stations.

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