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OSSB Modulation Schemes for Chromatic Dispersion Compensation in Optical WDM-RoF System

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ABSTRACT: Radio over Fiber (RoF) Transmission technology is efficient for the direct delivery of broadband wireless signals in access and metro networks. Communicating the signals through longer distances in aRoF system, different phase shifting values are introduced into the sidebands of the optical signal. To overcome this power fading effect and to ensure overall transmission performance in different communication distances, the signal shouldbe communicated in Optical Single Sideband (OSSB) format instead of Optical Double Sideband (ODSB) format. The impact of chromatic dispersion on the signals transported by the fiber link and its mitigation using different dispersion compensation techniques are analysed. It includes the optical single sideband transmission using Dual Electrode Mach Zehnder Modulator, external filtering using FBG and compensation using Chirped Fiber Grating. The results clearly depict that compensation using chirped grating is the best among the three methods.

KEYWORDS: Radio Over Fiber (RoF), Chromatic Dispersion, Fiber Bragg Grating, Optical Single Sideband (OSSB), Chirped Fiber Bragg Grating (CFBG)

I.INTRODUCTION

Radio-over-Fiber (RoF) transmission technologies combine the technical advantages of the optical and wireless communication systems. RoFtechniques have certain advantages, thereby it have gained popularity. Some of the advantages are high bandwidth, mobility, low losses, etc[1]. In RoF,the optical signal is being modulated at radio frequency and transmitted through the optical fiber. RoFimproves the flexibility of system and provides a very largecoverage area without increasing the cost and complexity of the system.The impact of fiber chromaticdispersion on the transported RF signals is the mostpredominant one. In RoF systems, the RF signal is used todirectly modulate the laser diode in the central site.The following intensity modulated optical signal consisting of the carrier and two sidebands. Optical Double-Sideband (ODSB) modulated signal is then transported over the length of the fiber tothe Base Station. At the optical receiver, individual sideband beats with theoptical carrier, thereby generating two beat signals whichconstructively interfere to generate a single component at theRF frequency. However, when the ODSB signal is transmittedover fiber, chromatic dispersion causes each spectralcomponent of the signal to experience different phase shifts depending onthe fiber link distance, modulation frequency, and the chromatic dispersionparameter of fiber[2]. These phase shifts results in the relative phasedifferences between the carrier and the individual sideband, andproduce a phase difference in the two beat signals at the RFfrequency, which results in a power fading of thecomposite RF signal. So filtering out one of the sidebands of the ODSB signal is used to mitigate chromatic dispersion and thereby generating Optical Single-Sideband (OSSB) modulation.

In this paper, three techniques namely the external filtering using FBG, OSSB with Carrier modulation using Dual Electrode Mach Zehnder Modulator(DEMZM) and Chirped Fiber Bragg Grating(CFBG)compensation.

II. RELATED WORK

In a WDM-RoF system chromatic dispersion causes RF power fading to the signals by its communication through long distances. In order to minimize this chromatic dispersion various techniques are used for its counter dispersion. In [2] authors describesdifferent modulation formats like OSSB and OVSB formats are described to increase the spectral

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efficiency and chromatic dispersion tolerance. Optical SSB is a spectral efficient transmission technique in which one of the sideband of double sideband spectrum is supressed while maintain the other. On the other hand in OVSB the sideband is fragmentary supressed. To provide the long-range transmission performance in different communication distances, communicating the RF signal in optical single sideband format instead of optical double sideband format has been commonly employed [3].

In [4] the authors describe the filtering of onesideband of an ODSB signal via an optical band pass filter(OBPF) or an optical Fiber BraggGrating (FBG). They propose and successfully demonstrate a microwave photonic filter based on phase modulationand a Fiber-Bragg-Grating-based Fabry–Pérotcavity etched in a high birefringence fiber. Authors [5] propose and demonstrate a simple and novel method to produce a quasi-single-sideband (QSSB) optical ultra-wideband (UWB) signal using a Dual-Drive Mach-Zehnder Modulator. To analyse the transmission performance of the generated QSSB UWB signal, an analytical model is introduced with the evolution of the waveforms and the spectra with the transmission distance studied. The theoretical analysis is confirmed by an experiment. Eye diagrams, electrical spectra and bit-error rate measurement show that the novel system has a good tolerance to the chromatic dispersion (CD) of single mode fiber (SMF).

II.SYSTEM MODELLING

AnRoF optical communication system involving external modulation is as shown inFigure 1. To evaluate its performance, a 100Gbps/0.1 THz RF signal generated from mixing a 100 Gbps pseudo-random binary sequence stream with a 0.1THz sinusoidal signal is initially modulated with a optical carrier via a LiNb MZM.

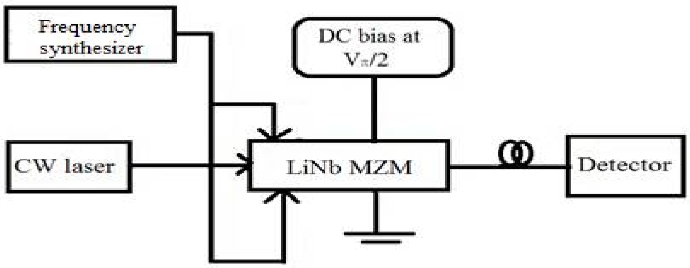

Figure 1: RoF Optical communication system

The LiNb MZM is induced by an RF signal of frequency 0.1THz from the Frequency synthesizer which is fedto the two arms of the Mach-Zehnder modulator via a fork. The CW laser power is 10dBm and frequency 193.1THz.The half wave switching voltage $V_\pi$ofLiNb MZM is 4V. After being modulated bythe Mach-Zehnder modulator, the intensity modulated optical signal consisting of carrier and two sidebands (Optical Double-Sideband (ODSB) modulation) is transmitted through the fiber and detected at the receiver side. At the optical receiver,theSidebands beats with the optical carrier and generates two beat signals which constructively interfere to produce a single component of RF frequency. When the ODSB signal is transmitted over fiber, chromatic dispersion causes individual spectral component to experience different phase shifts. These phase shifts results in the relative phase differences between the carrier and individual sideband, and generate a phase difference in the two beat signals, which results in a power degradation of the RF signal.In order to overcome this RF power fading effect, the signal should be communicated in Optical Single-Sideband (OSSB) format instead of ODSB. The techniques used for OSSB transmission are detailed below.

A.Optical single sideband transmission using FBG

The dispersion impact can be optimized by transmitting only one sideband of the modulating signal. In this case a Fiber Bragg Grating is used to supress one of the sidebands [4].The intensity modulated optical carrier from the LiNb MZM is fed to FBG for OSSB with carrier generation, then OSSB modulated carrier signal is multiplexed at the multiplexer and transmitted through the optical fiber and demultiplexed at the demultiplexer. The signal is then detected by the photodetector at the receiver side.

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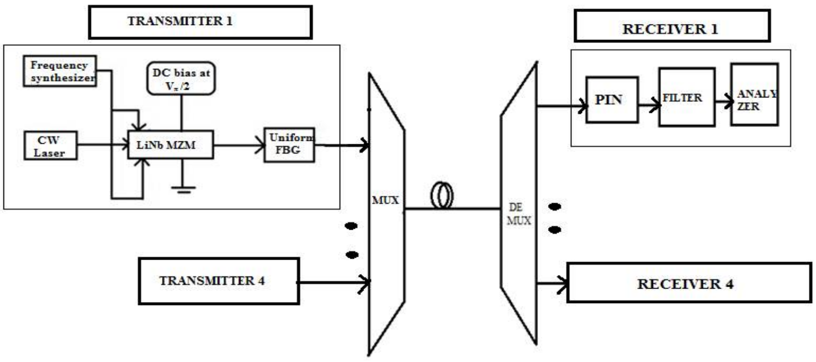

Figure 2: Block diagram of 4 user RoFsystem with FBG at the Transmitter end

B. Optical single sideband transmission using DEMZM

The Dual electrode Mach-Zehnder modulator (DEMZM) is biased at quadrature pointto produce optical single sideband with carrier. The LiNb MZM is driven by an RF signal from the Frequency synthesizer is fed to the two arms of the Mach-zehnder modulator with a90^0phase shift via a fork. After being modulated at the Mach-zehnder modulator, the intensitymodulated optical carrier in OSSB format is transmitted through the optical fiberand detected by the photodetector. This compensation scheme is depicted in Figure 3.

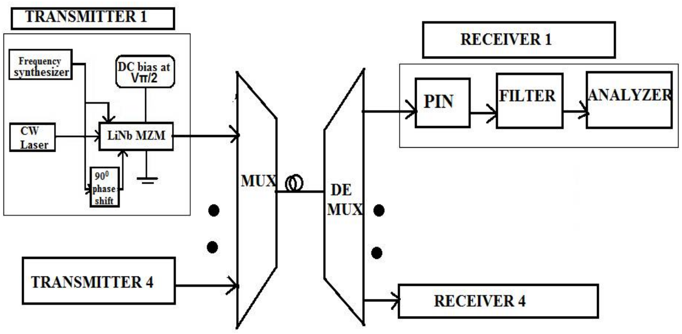

Figure 3: Block diagram of 4 user RoFsystem with DEMZM at the Transmitter end

C. Optical single sideband transmission using CFBG

Third technique that is used to eliminate chromatic dispersion in fiber links is using linearlychirped fiber bragg gratings. This method is depicted in the Figure 4.The intensitymodulated optical carrier from the LiNb MZM is fed to Chirped FBG for OSSB withCarrier generation, then OSSB modulated carrier signal is transmitted through the opticalfiber and detected by the photodetector.

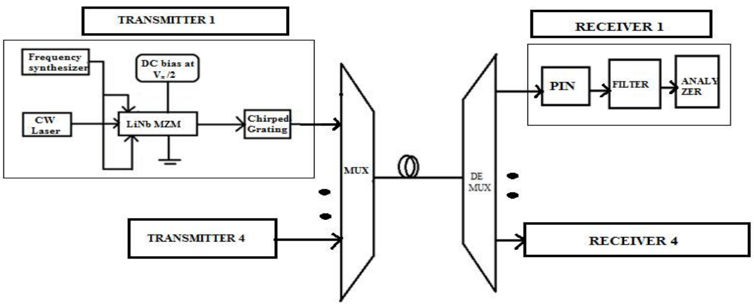

Figure 4: Block diagram of 4 user RoFsystem with CFBG at the Transmitter end

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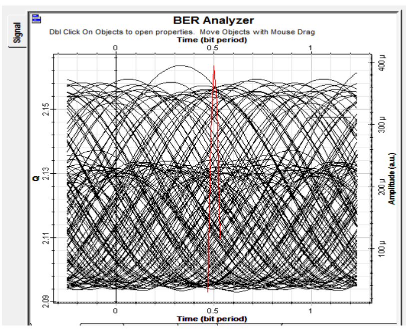
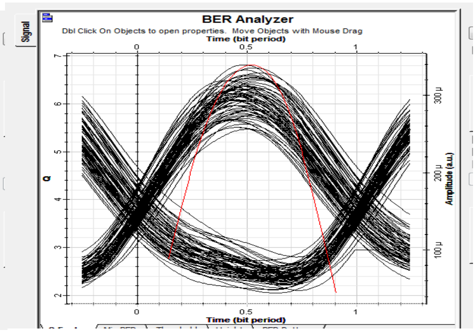
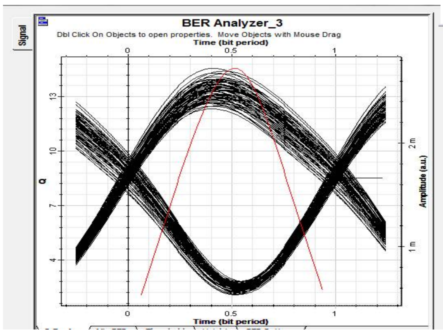
III. SIMULATION RESULTS AND DISCUSSIONS

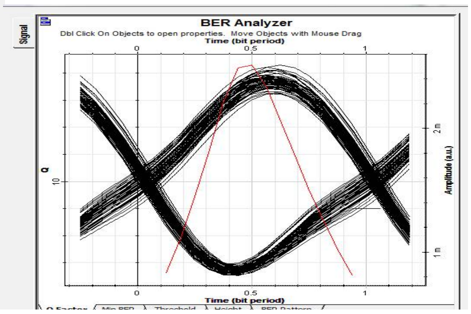
The eye diagrams of RoFoptical communication system obtained for Fiber bragg grating, Dual ElectrodeMach-Zehnder Modulator and for Chirped grating are shown in the figure. The system is operated at a Bit rate of 100 Gbps,Input power of 10 dBmand RF frequency of 0.1THz.





(a) (b)





(c) (d)

Figure 5: Eye diagram ofRoF system (a) without optical filter at the transmitter end (b) with FBG at the transmitter end(c) with DEMZM at the transmitter end and (d) with CFBG at the transmitter end

When the ODSB signal is transmitted through the optical fiber, RF power fading occurs. Therefore the eyediagramobtained is distorted as shown in Figure 5(a).

But when dispersion compensation is applied better eye diagram is generated. It indicates that dispersion has been reduced. The eye diagrams of the three compensation schemes are shown in Figure5(b),5(c), and 5(d).

Table 1: Q factor of various dispersion compensation techniques

Dispersion Compensation Techniques	Q Factor
OSSB using FBG	6.81
OSSB using DEMZM	14.55
OSSB using CFBG	18.14

From Table 1, It is clear that the compensation using CFBG shows a better Q factor among the other two schemes.Figure 6 represents the spectrum plot for ODSB signal in a RoF system without dispersion compensation at the transmitter end. It is clear that optical double side bands are presents in the transmitted signal, if there is no dispersion compensation at the transmitter end.

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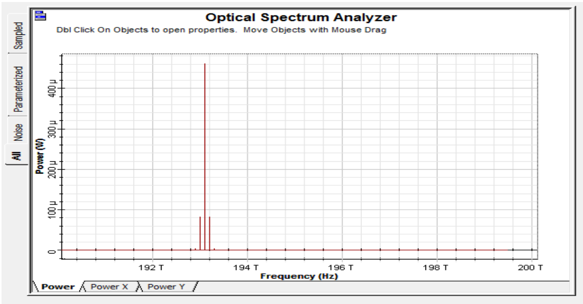
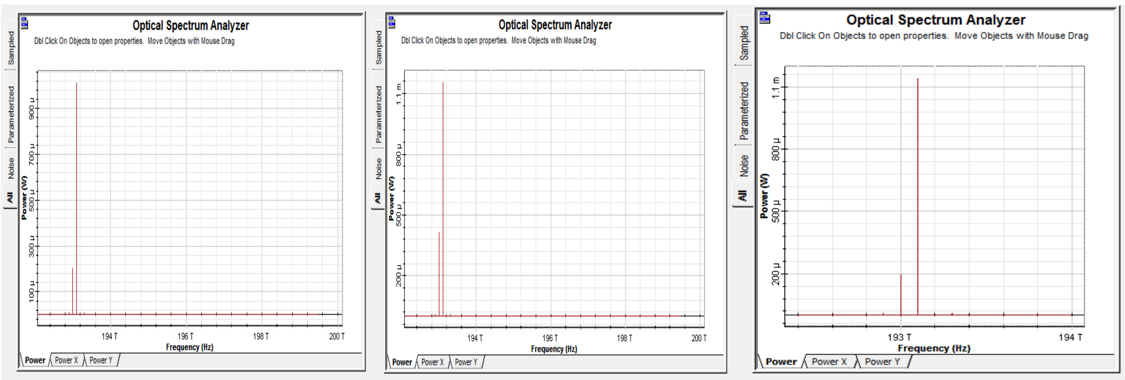


Figure 6: Spectrum showing ODSB signal without optical filter at the transmitter end

Figure 7(a) shows OSSB signal after FBG. 193.2 THz frequency is filtered out in the FBG. The OSSB output spectrum is also obtained for DEMZM and CFBG at the transmitter end.



(a) (b) (c)

Figure 7: Spectrum analyzer output showing OSSB signal for(a)FBG (b) DEMZM and (c)CFBG

IV.CONCLUSION

The impact of chromatic dispersion on transmission of intensity modulated optical carrier through the fiber link in a WDM-RoFSystem is discussed. Simulated OSSB with carrier modulation using FBG, DEMZM and Chirped FBG.The three compensation techniques were compared by plotting the eyediagrams. The Q-factors of all the dispersion compensation schemes in a WDM-RoF system is obtained. It is found that the compensation using Chirped Fiber Bragg Grating showss a better performance compared to the other two schemes. At CFBG different velocity of propagation of various spectral components causes the spreading of pulse, hence the pulse becomes broadened and its power improves as a result of linear chirp parameter.

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