ROF Communication System Performance Enhancement Using Both Modified Differential Phase Shift Keying (DPSK) and Sub-Carrier Multiplexing Technique

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Abstract—The increasing demand for bandwidth in data communication motivates the development of high-speed and low-cost optical links. In this paper, Sub-Carrier Multiplexed (SCM) Radio over Fiber System (ROF) with modified DPSK modulation technique has been investigated by using a relatively new type of laser called Vertical-Cavity Surface-Emitting Laser (VCSEL). A simulation model has been developed to extend both transmission distance up to 200 Km and bit rate 20Gbp/s with single mode fiber (SMF). Using various dispersion compensation techniques namely FBG (Fiber Bragg Grating), OPC (Optical Phase Conjugation) and DCF (Dispersion compensating Fiber) lead to compensate the dispersion and enhance bit rate up to 20Gbps through SMF. EDFA (Erbium-doped fiber amplifier) used to amplify signals. The performance of various dispersion compensation techniques has been studied through software OptiSystem Version 14.1. BER (Bit Error Rate) and Quality Factor (QF) have been observed to analyze the performance of these various compensation techniques to mitigate dispersion caused in the system.

Index Terms—ROF, DPSK, Q-factor, SCM, VCSEL, DCF, FBG, OPC, SMF and BER

I. Introduction

In ROF, radio frequency (RF) signals are transmitted after they are modulated to form an analog optical connection. The RF signals are transmitted downlink and uplink, i.e. to and from Central Stations (CS) to Base Stations (BS). Digital modulation is mostly used in RF, in any common form as TCM, QAM, PSK, etc. [1]. The optical signal which is intensity modulated is then transferred over the optical fiber to the BS remote antenna unite (RAU). At the RAU, direct detection recuperates the transmitted RF signal in the PIN photodetector. The Intensity Modulation with Direct Detection (IM-DD) is a technique of conveying RF signals over the fiber, and it is the least complicated form of the ROF connection [2]. In the Wireless Local Area Network (WLAN), a very high speed multimedia can be supported in real time by using the optical fiber [3]. The benefits and advantages of the ROF distribution are high bandwidth, low attenuation, immunity to radio frequency interference, low power consumption, multi-service capability, easy installation, maintenance and dynamic resource allocation [4].

The DPSK signal and ROF techniques together have become promising solutions in implementing future wideband wireless networks. The ROF scheme can be utilized for wireless signals distribution [5]. The DPSK eliminates the cross-phase modulation (XPM) and provides a significant improvement in the receiver sensitivity. The employment of balanced receivers have produced impressive transmission results. Moreover, the implementation of DPSK with direct detection techniques have supported high data rates at 10 and 40 Gb/s [6].

At the receiver, a coherent reference signal is needed to detect a phase modulated signal, but if PSK and differential encoding are integrated together at the side of transmitter then the digital modulation technique is marked as DPSK. For the transmission of (0), the phase is fixed whereas for transmission of (1), the phase of the signal is developed by 180°. To determine the relative phase change between the symbols transmitted, the path of the changing phase information becomes fundamental [7].

For supporting high capacity transmissions at low cost and enabling fiber based wireless, access SCM has been used. An effort has been made to minimize the electronic components number for the detection of baseband signals. Without-any electrical demodulation module baseband signals are directly detected from optical signals. This technique overcomes electronic components restrictions and reduces system cost simultaneously [8]. SCM-ROF is a hybrid technique that synergizes the optical and the radio communication domains, and transmits the RF signals from BS to RAU on optical fiber connection to use both SCM and ROF technology using a comparatively recent type of laser called VCSEL as the optical source. [9].

VCSELs have been used widely for optical interconnections and communications as they have a low-cost testing and packaging. The loss and dispersion in optical fiber cables limit the transmission of lasers wavelengths shorter than 1 μm. On the other hand, 1.5 μm VCSELs are perfect candidates for fiber-optic communications because of the utilization of EDFAs enables possible long-distance broadcasting and applications systems [10].

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The Mach-Zehnder optical modulator (MZM) is based on the external modulation principles. It uses a technique where the light is classified in two directions and the current of modulation signal flows through the center of every branch through its propagation through a waveguide. A Mach-Zehnder interferometric modulator is a dual waveguide device. A MZM is commonly constructed so the phase difference between the two optical waveguides that propagate the split beams is 0 when voltage is not being applied. [11].

II. Various Dispersion Compensation Techniques

Various dispersion compensation technologies were proposed as discussed below in order to minimize the dispersion, expand transmission distance in systems operating at higher bit rate and increase efficiency of the network.

A. Fiber Bragg Grating (FBG)

FBG is based on the principle of Fresnel reflection, where light travelling between media having various refractive indices may reflect or refract at the interface. At a specific length the refractive index will alternate also small amount of light is reflected during refraction. At a specific wavelength, one large reflection is combined by these reflected light signals in which the grating period is half the input lights wavelength approximately. This is Bragg condition on the wavelength at which reflection take place is named Bragg wavelength (λβ=2 $\bar{n}$)-changes along the grating length, When the Bragg condition is satisfied, the frequency component is reflected. The grating dispersion D_g

$$D_g = \frac{2\bar{n}}{C(\Delta\lambda)}$$

where $\bar{n}$ is average mode index and C is the velocity of light. It performs as a dispersion compensator in optical system transmission which is utilized to compensate chromatic dispersion.

B. Dispersion Compensating Fiber (DCF)

DCF is more stable as they have higher negative dispersion coefficient so the components of DCF are difficult affected by bandwidth and temperature and therefore can be connected to the transmission fiber having the positive dispersion coefficient. Therefore the total dispersion of the link is zero. To compensate the positive dispersion of the standard fiber and achieve the dispersion compensation, In Pre dispersion Compensation fiber (Pre DCF), is placed before the Standard Single Mode Fiber (SSMF) whereas in post dispersion Compensation fiber (Post DCF) is placed after SSMF and In Symmetrical dispersion compensation fiber (Symmetrical DCF) is placed before as well as after SSMF.

C. Optical Phase Conjugation (OPC)

OPC is utilized to compensate Kerr effect and chromatic dispersion. Through OPC, the ability to compensate for Self-Phase modulation was calculated numerically. Because of this, Self-Phase Modulation induced phase distortions after conjugation un does phase distortions before conjugation. The Prior realizations of OPC were based on stimulated Brillion scattering. OPC is utilized to reverse phase of beam of light and the phase propagation direction. The reversed beam is named conjugated beam. OPC must produce a conjugated signal with a proper optical intensity, it must show a large available conjugation bandwidth, During the OPC, it should not introduce any distortion of the signal neither in terms of chirp nor of minimization of the optical signal to noise ratio (OSNR) and it must be transparent to signal bit-rate and modulation format it and [12]

The performance enhancement of SCM ROF System is investigated by this paper as considered in [8]. By using VCSEL with keep temperature environment constant and different dispersion compensation techniques namely FBG, OPC and DCF lead to compensate the dispersion and enhance both transmission distance up to 200 Km and bit rate 20Gbp/s with SMF and reduce system coast. The choosing of VCSEL Laser to study SCM-ROF system here for long haul transmission because of various advantages of

VCSEL Laser over conventional lasers like better wavelength stability, lower manufacturing cost, high temperature operation up to 80℃ and lower threshold currents. The nonlinear distortion and signal to noise ratio are investigated and evaluated in case of long-range multi-carrier transmission.

III. Simulation Setup

Simulation is done using simulation software Opti-system version 14.1. Fig. 1(a), Fig. 1(b), Fig. 1(c), Fig. 1(d), Fig. 1(e) Show Blocks diagrams for various dispersion compensation techniques named FBG, OPC and DCF lead to compensate the dispersion and enhance both transmission distance up to 200 Km and bit rate 20Gbp/s with SMF. In the OPC, Pre, Post and Symmetrical DCF the highly nonlinear fiber with 0.5Km. The Table I shows the simulation parameters for SMF and DCF optical fiber. At the transmission, the data signal is generated by three Pseudo-Random Bit Sequence Generators (PRBS) where the bit rate is set at 10 Gbps and the chosen working frequencies are 10 GHz, 15 GHz, and 20 GHz. The data is then modulated by a DPSK modulator. These signals are passed through band-pass filters (frequencies same as carrier frequencies and bandwidth= 1.5xBit Rate) which is used at both transmitter and receiver to remove unwanted frequencies and obtain only the required spectrum.

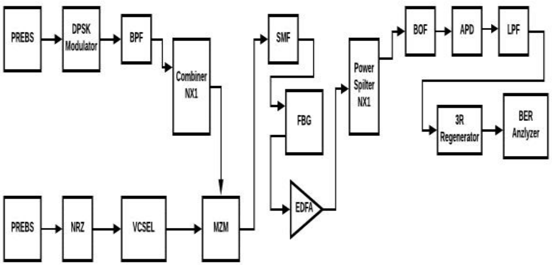

Fig. 1. (a) Block diagram of FBG dispersion compensation with ROF using DPSK technique.

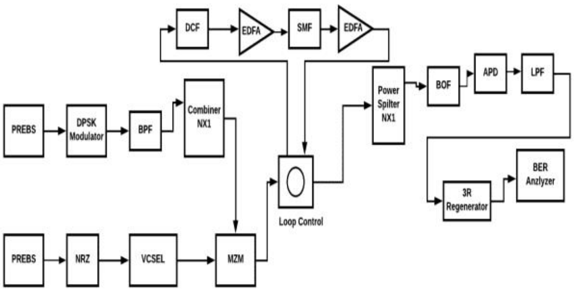

Fig. 1(b). Block diagram of Pre compensation DCF with ROF using DPSK technique.

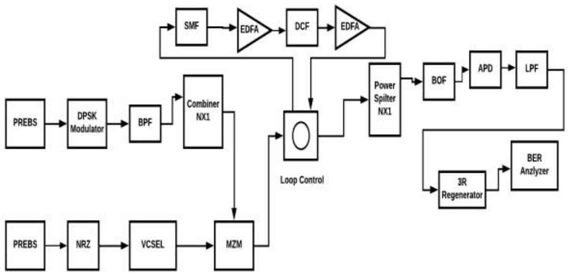

Fig. 1(c). Block diagram of Post compensation DCF with ROF using DPSK technique.

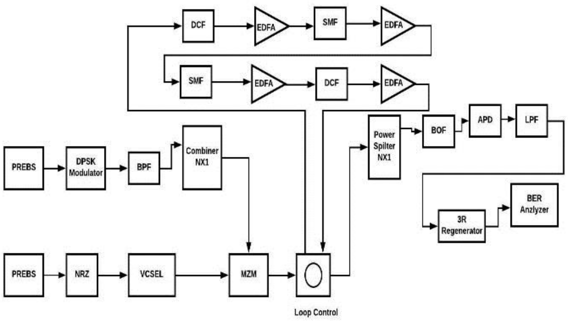

Fig. 1(d). Block diagram of Symmetrical dispersion compensation with ROF using DPSK technique.

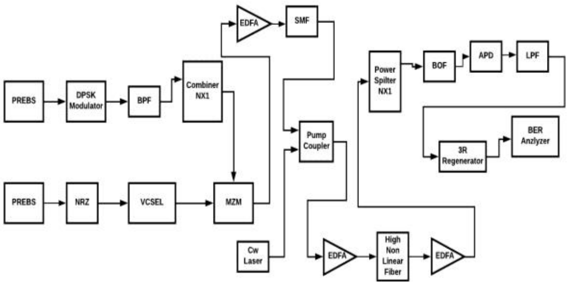

Fig. 1(e). Block diagram of OPC dispersion compensation with ROF using DPSK technique.

An electrical power combiner is used to combine these signals. AMZM is used to modulate an optical carrier of frequency 193.1 THz with the combined signal. The optical modulation that consists of VCSEL was used instead of the continuous wave laser that was used in the traditional system [8] and different dispersion compensation techniques namely FBG, OPC and DCF lead to compensate the dispersion and enhance both transmission distance up to 200 Km and bit rate 20Gbp/s with SMF and DCF, reduce system coast, enhance SCM ROF system performance and increasing bit rate up to 20 Gbps. Table II shows the simulation parameters for FBG. Also, long haul distances can be supported up to 200 Km and MZM prepares the electrical signal to be transported through SMF. These signals are amplified by EDFA. At the receiver, the optical signal is then passed through an optical band pass filter (at frequencies 193.11 THz, 193.115 THz, 193.120 THz and bandwidth= 1.5 x Bit rate). This filtered signal is then passed through Avalanche Photo diode (APD) instead of Photo Intrinsic diode which will convert this optical signal directly into baseband signal. Low pass filters (Cutoff frequency = 0.75 x Bit rate Hz) are used to filter higher frequency components and finally we regenerate the desired signal. The signal is then fed into BER analyzers for data analysis [8].

TABLE I. SIMULATION PARAMETERS [13]

Fiber type	Loss (dB/Km)	Dispersion (Ps/nm/Km)	Dispersion Slope (Ps/nm2/Km)	A eff (μm2)
SMF	0.22	16	0.08	90
DCF	0.5	-96	0.22	-85

TABLE II. SIMULATION PARAMETERS FOR FBG

Parameters	**V a l u e s**
Frequency(THz)	193.1
Power (dBm)	0
Line Width (MHz)	10
Attenuation (dB/Km)	0.25
Dispersion (ps/nm/Km)	5
Dispersion Slope (ps/nm/Km)	0.08
Differentia Group delay (ps/Km)	3
SMF Reference wavelength (nm)	1550
Apodization Function FBG	Tanh
Tanh Parameter	0.5
Chirp Function	Linear
Chirp Value	0.0001
Modulator	Mach Zehnder
Photodetector	APD
Initial Phase (deg)	0
Bit Rate (Gbps)	20

IV. Simulation Results and Discussions

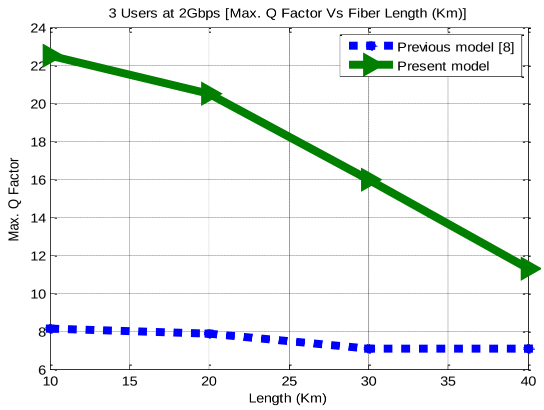

Fig. 2(a). Max. Q Factor Versus Fiber Length at bit rate 2Gbps.

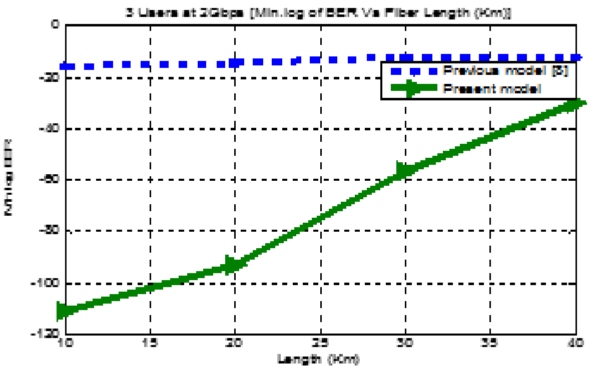

Fig. 2(b). Min. log of BER Versus Fiber Length at bit rate 2 Gbps.

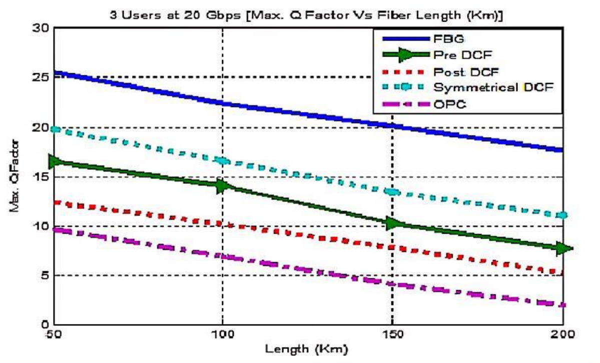

Fig. 3. Max. Q Factor Versus Fiber Length for various dispersion compensation at bit rate 20 Gbps.

Fig. 2. Explains traditional systems [8] and the new system comparison. In this case, number of users and bit rate are kept constant and outputs are observed by varying fiber length from 10Km to 40Km. The values of Max. Q Factor and Min. BER against fiber length are plotted on the graphs. From graphs 2(a), 2(b) we can observe the value of Max. Q factor and value of Min. BER for the new system increasing from the traditional system. In Fig. 3 explains comparison between different dispersion compensation techniques namely FBG, OPC and DCF lead to compensate the dispersion and enhance bit rate up to 20Gbps through SMF for the new system at bit rate 20Gbps has better enhancement than the traditional system [8] and explains the value of Max. Q factor and value of Min. BER using DPSK modulation technique with VCSEL and different dispersion compensation techniques to enhance SCM ROF system performance with SMF. Also, long haul distances can be supported up to 200 Km.

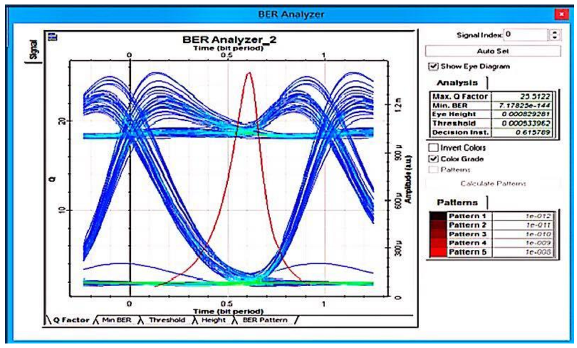

Fig. 4(a).Eye diagram for FBG dispersion compensation at 50 Km at 20 Gbps.

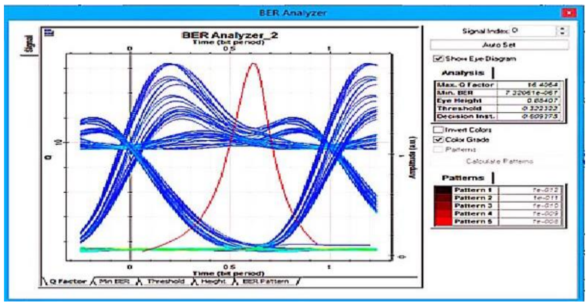

Fig. 4(b). Eye diagram for Pre dispersion compensation at 50 Km at 20 Gbps.

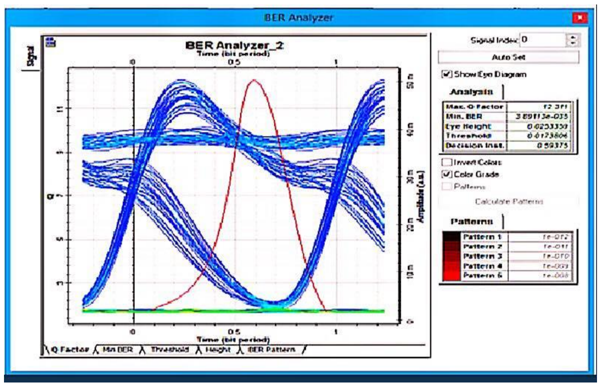

Fig. 4(c). Eye diagram for Post dispersion compensation at 50 Km at 20 Gbps.

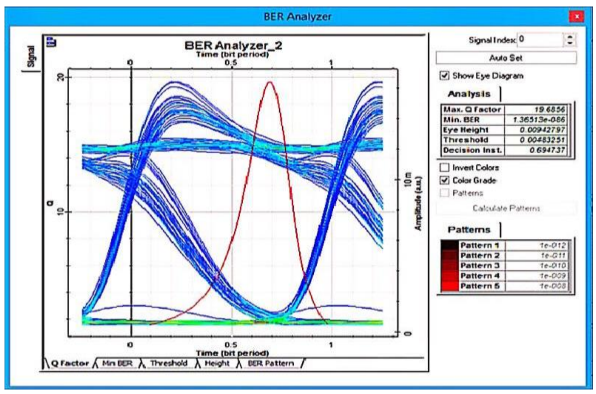

Fig. 4(d). Eye diagram for Symmetrical dispersion compensation at 50 Km at 20 Gbps.

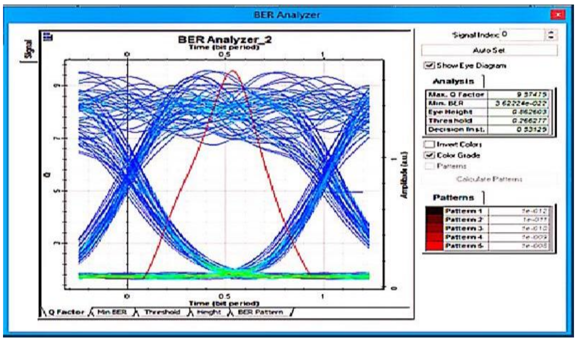

Fig. 4(e). Eye diagram for Symmetrical dispersion compensation at 50 Km at 20 Gbps.

The graphs for Q factor, min BER and eye diagram are shown in Fig. 4(a), Fig. 4(b), Fig. 4(c), Fig. 4(d), Fig. 4(e). Max Q factor is in FBG dispersion technique in all the simulations. The performance of various dispersion compensation techniques is evaluated by varying the length of the fiber from 50 to 200 Km with bit rate 20 Gbps and by MZM. FBG gives better result than other techniques when MZM is used with APD instead of photo intrinsic diode (PIN).

V. Conclusion

In summary, from the results it is concluded that FBG and DCF DPSK techniques have better results than OPC. Dispersion Compensating Fiber techniques when contains three type named Pre DCF, Post DCF and Symmetrical Compensating Fiber and among them Symmetrical DCF is much better than pre and post DCF when implemented with ROF using DPSK technique at bit rate 20Gbps and transmission distance from 50Km to 200Km. OPC technique shows less dispersion when MZM is used with Avalanche Photo diode instead of Photo Intrinsic diode.

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