ANALYSIS OF 40GBPS DUOBINARY MODULATION FOR DIFFERENT TERRESTRIAL OPTICAL COMMUNICATION LINK

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Abstract- This paper presents the simulative analysis of duobinary modulation scheme at the bit rate of 40Gbps for dispersion compensated Amplified Spontaneous Emission (ASE) –noise-limited optical communication link. The link performance analysis has been carried out for different types of commercially available optical fiber: SMF, LEAF, Vascade LEAF, Vascade LS+, Vascade R1000. The investigation presented in the paper helps in selecting the best fiber for long-distance reliable communication.

Index Terms- Duobinary, LEAF, SMF, VLEAF, VLS+, VR1000.

I. INTRODUCTION

The growing appetite for higher data rate has started an era of faster and reliable optical communication technology and led to transmission of 40Gbps single channel optical communication infrastructure [1]-[3].

The duobinary modulation scheme is the most promising candidate for high speed optical communication systems to provide a improved spectral efficiency and reduces the adverse effect on performance duo to dispersion and nonlinear effects. Till early 1990s, the most widely used technique was direct modulation of semiconductor laser. But, direct modulation of laser has several drawbacks, as it induces unwanted chirps which lead to spectral broadening of the signal, thus resulting in severe dispersion penalties. Directly-modulated optical signal has fluctuations in intensity duo to semiconductor laser's Relative Intensity Noise (RIN). For high speed data transmission direct modulation is generally not preferred because laser phase noise is introduced duo to nonzero line-width of laser source. Duo to this for high speed long distance communication external modulation has been an inevitable choice [4]. If laser diode is directly modulated, it will lead to large amount of wavelength chirping. This could be avoided by use of external modulators. There are mainly two types of external modulators viz. Electro-Optic Modulators (EOM) and Electro-Absorption Modulators (EAM) [5]. The EOM (band gap energy changes with applied electric field) is mostly used because of many advantages. It offers high extinction ratio, linear response characteristic, and capability of controlling phase, amplitude or frequency of the light wave carrier. The EOM is capable of supporting high speed modulation even for very low value of driving voltage [6].
In this paper, we have analysed the performance of duobinary modulation scheme for five different fiber types namely single mode fiber (SMF), large effective area fiber (LEAF), Vascade LEAF (VLEAF), Vascade LS+ (VLS+), Vascade R1000 (VR1000). These fibers are manufactured by Corning Company.
The organization of paper is as follows: duobinary transmitter module is described in Section 2, Section 3 deals with simulation setup. Results are reported in Section 4 and findings are concluded in Section5.

II. DUOBINARY TRANSMITTER MODULE

Two types of modulators are used to modulate the data in optical domain viz. optical intensity modulator and optical phase modulator. An electro-optic phase modulator (EOPM) comprises only one electrode. When the electrode is given driving voltage, the electro-optic waveguide refractive index changes accordingly, this slows down the light wave and thus produces a delay on the optical signal. The produced delay corresponds to phase change (as represented in Eq.(1)), thus the phase of the light wave carrier is manipulated by an EOPM [7].

$$\phi_{db} = \frac{\pi(V_{db}(t) + V_{db_{bias}})}{V_{db_\pi}} \qquad (1)$$

Where, V_{db_π} is the required driving voltage to create the phase shift of π, $V_{db}(t)$ represents a time-varying driving signal voltage and $V_{db_{bias}}$ represents dc bias voltage.

Optical field E_{db_o} at the output of the EOPM is represented as follows:-

$$E_{db_o}(t) = E_{db_i}(t)e^{j\varphi_{db}(t)} \qquad (2)$$

Two EOPMs are used in a parallel structure to construct optical intensity modulator widely known as Mach-Zehnder intensity modulator (MZIM) [8], [9]. Input optical signal is first passed through a splitter, and the equally splited optical input signal is fed to two arms of the MZIM which are EOPMs to modulate the phase of the optical signal. At the output, two arms couple either constructively or destructively to generate intensity modulated optical pulses. In dual-arm MZIM the driving voltages $V_{db_1}(t)$ and $V_{db_2}(t)$ are of opposite polarity but same magnitude (i.e., $V_{db_2}(t) = -V_{db_1}(t)$) and thus, the chirping effect in the modulation is completely eliminated. The transmitted optical field can be represented as:

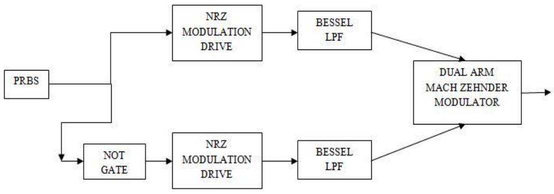


Fig. 1 Dual arm MZIM consisting duobinary transmitter module

$$E_{db_o}(t) = \frac{E_{db_i}(t)}{2}\left[e^{j\pi\frac{(V_{db}(t)+V_{db_{bias}})}{V_\pi}} + e^{j\pi\frac{-(V_{db}(t)+V_{db_{bias}})}{V_\pi}} \right] \quad (3)$$

$$= E_{db_i}\cos\left[\frac{\pi(V_{db}(t)+V_{db_{bias}})}{2V_\pi}\right]$$

At high data rate dual-arm MZIM is mostly used for the transmitter design, but, dual arm configuration needs more strict requirement of symmetry to be met [10], [11].

Fig. 1 represents the dual-arm MZIM based duobinary transmitter used in this work. The duobinary transmitter comprises a data source (pseudo random bit sequence generator), non-return-to-zero (NRZ) modulation driver, electrical Bessel low pass filter (LPF), logical not gate, dual arm Mach-Zehnder modulator (MZIM) and a optical laser source. Two modulation drivers are fed with the pseudo random sequence generated by data source at 40Gbps, one directly and another after logical not gate. After this, these two electrical signals are fed to Bessel filter of 4th order. The optical laser source emits the continuous wave (CW) at a center frequency of 1550nm. The output of laser source and two outputs of Bessel filter are fed to dual arm MZIM to generate duobinary optical signal.

III. SIMULATION SETUP

The simulation setup for 40Gbps duobinary modulation system for optical signal transmission is shown in Fig. 2 for ASE noise limited fiber channel. In this paper the simulation platform is OptiSystem.

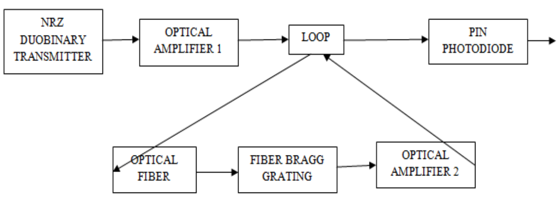


Fig.2 Simulation for 40Gbps duobinary transmission

The offset voltage of MZIM is 0.5V with extinction ratio of 20dB to provide 3dB average power reduction duo to modulation. Specification of PIN photo detector is as follows:- 0.63992 quantum efficiency, 0.8A/W responsitivity, 0.1nA dark current.

The gain of the Optical Amplifier 1 is 10dB with noise figure of 4dB, the gain of Optical Amplifier 2 is 12dB with noise figure of 4dB. The fiber bragg grating (FBG) is used to compensate for dispersion and to produce a 0ps/nm*km of dispersion per fiber span.

In this paper, we have analyzed the performance of duobinary modulation for different terrestrial optical system comprising of commercially available fiber. Table I gives the specification of SMF, LEAF, VLEAF, and Table II gives the specification of VLS+, VL1000, VS1000. Except SMF, the rest of the fibers belong to the class of non-zero-dispersion shifter fiber (NZ-DSF). The Vascade family of fiber are used for submarine application duo their high tolerance to harsh environment condition. But, in this paper, we have proposed their deployment in terrestrial optical communication link.

Vascade R1000 fiber is cascade connection of Vascade L1000 followed by Vascade S1000. In this simulation ratio of VL1000 and VS1000 is kept 8:3. The length of each fiber in one loop is 50km.

Table I Parameters of different fibers at 1550nm-part 1

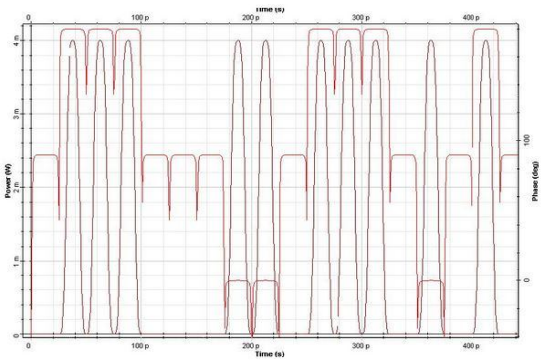
Fiber	SMF	LEAF	VLEAF
Attenuation (dB/km)	0.2	0.2	0.2
Dispersion (ps/nm*km)	+16.5	+4.0	-4.0
Dispersion Slope $(ps/nm^2 * km)$	+0.07	+0.1	+0.12
Effective Area (μm^2)	77.95	72	65

Table II Parameters of different fibers at 1550nm-part 2

Fiber	VLS+	VL1000	VS1000
Attenuation (dB/km)	0.201	0.187	0.235
Dispersion (ps/nm*km)	-3.0	+18.5	-38.0
Dispersion Slope $(ps/nm^2 * km)$	+0.05	+0.06	-0.12
Effective Area (μm^2)	48	100	27

IV. RESULTS AND DISCUSSION

Fig. 3 represents the generated duobinary signal's intensity and phase. It could be seen that the phase difference between consecutive 1's separated by odd number of 0's is 180^0, whereas the 1's which are separated by even number of 0's , have phase shift of 0^0.



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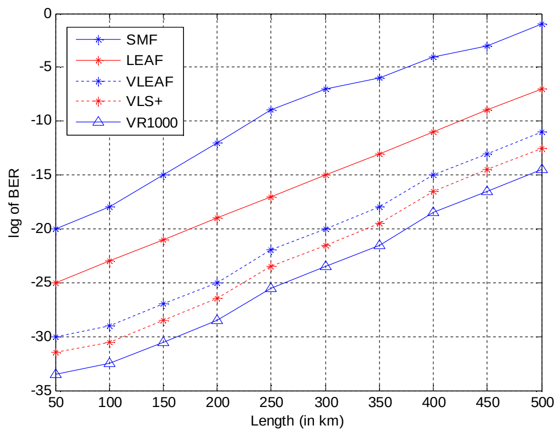

Fig. 4 Length v/s Log of BER

Fig. 4 represents the plot of length v/s log of ber. It could be seen from the plot that as we move from SMF to VR1000 the log of ber has less value, which indicates better ber performance of the link under the use of Vascade family fiber. The LEAF performs better than SMF but its performance is poor in comparision to Vascade family fiber. Among Vascade family fibers VR1000 gives optimum performance. At 300km the log of ber for SMF is -7, but for VR1000 it is -23.

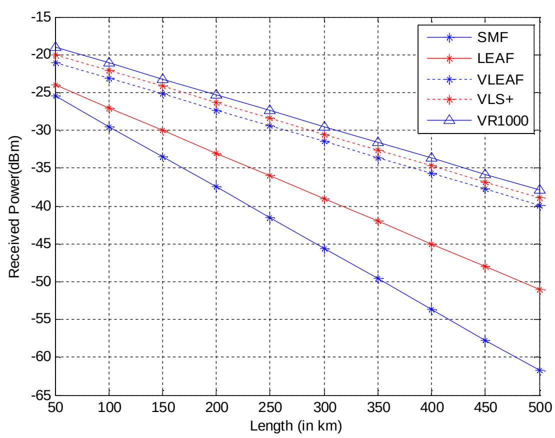

Fig. 5 Length v/s Received Power

Fig. 5 represents the plot of length v/s received power. It could be seen from the plot that as we move from SMF to VR1000 the drop in received power is less with distance. This is why we get better ber performance for Vascade family fibers. The drop in received power is highest for SMF, it is comparatively low for LEAF and for Vascade family fiber it is the least. At 300km, the received power for SMF is -46dBm and for VR1000 it is -29dBm. There is significant improvement in received power.

Fig. 6 represents the plot of OSNR v/s log of ber. It could be seen that as we move from SMF to VR1000, with less OSNR we are getting better BER. With OSNR of 20dB the log of ber is -9 for SMF but for VR1000 it is -25.5. The LEAF performs better than SMF, but Vascade family fibers perform better than LEAF. The VR1000 performs the best out of all the above fiber.

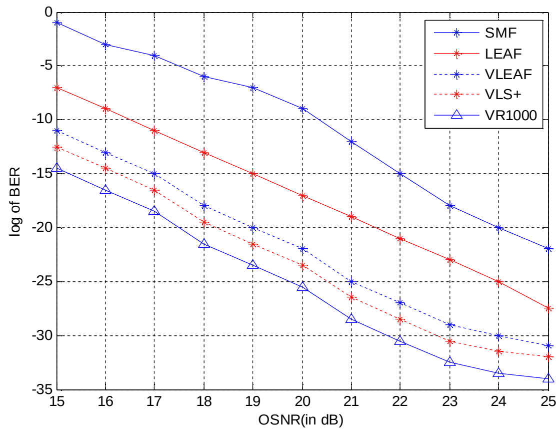

Fig.6 OSNR v/s log of BER

CONCLUSION

This paper reports the simulative analysis of different terrestrial optical systems for 40Gbps duobinary transmission. The comparision result shows that use of NZ-DSF fibers improves the system performance signifincantly. The Vascade family fibers provide the more improved performance. Out of the Vascade family fibers considered in this simulation VR1000 gives best performance. This fibers are manufactured by Corning Company. These fibers could be deployed for even high bit rate and long-haul communication.

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