Analysis of modulation formats employing Mach-Zehnder Optical modulator for the deployment of RoF System

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Abstract- *This paper presents a Semiconductor Optical Amplifier (SOA) based Radio over Fiber (RoF) system to evaluate the performance of different modulation formats in a 2.5 Gbps communication link. The various modulation formats for the deployment of RoF system has been analyzed at different fiber length using OptiSystem (14.0) based upon performance metrics such as Q-factor, BER and Eye Height. The simulation results reveal that the RZ modulation format is the best feasible modulation format for future high data rate applications in comparison to other modulation formats.*

Keywords- EDFA, MZM, NRZ, RZ, SOA

I. INTRODUCTION

The RoF technology serves as a cost effective last-mile access solution for the future generation communication networks [1]. The infrastructure and operation cost of RoF system is lowered by considerable amount, by sharing common Central Station amongst Base Stations. RoF technology is attributed to be the elixir for implementation of high performance communication system. In RoF transmission systems, modulation of the electrical signal can be accomplished onto the optical carrier by employing either direct or external modulation and the modulated signal is propagated over the optical fiber. Direct modulation of the optical sources is the intelligible way of intensity modulation. However, when the modulation frequency increases, the relative intensity noise (RIN) and distortions affect the long distance signal transmission. Therefore, Mach-Zehnder Modulators (MZMs), which exhibit as the most prominent, cost-effective and low-complexity external modulation approach in optical communications, can elucidate the intricacy by providing minimum optical loss and highest power handling capacity [2].

II. BACKGROUND AND RELATED ISSUES

Extensive researches in RoF systems has coveted on enhancing the system performance by applying innovation techniques based on these modulation schemes. EDFA with external modulation technique [3] reduces the non-linear distortion and improves the received electric power by -11 dB [4]. High SOA input power [5] improved the Optical Signal to Noise Ratio (OSNR). SOA employ-ed for the generation of millimeter-wave signal provides low phase noise by beating the light signal and pump signal, therefore SOA must be incorporate in future RoF system to reduce the noise generation [6]. The high electronic bandwidth in optical communication can be accomplished by employing advance modulation formats [7].Among various modulation formats that have been employed earlier is, Non-Return to Zero (NRZ), Differential Phase Shift keying (DPSK), Quadrature Phase Shift Keying (QPSK) are influenced by channel dispersion and non-linear impairments [8]. The duobinary modulation formats have been analyzed in 40 Gbps link which implies that DB-RZ outperforms over DB-NRZ [9]. RZ modulation format have been implemented before [9], but the performance has not been directly compared to more advance modulation format for millimeter wave signal. Previously NRZ format has been employed in lightwave communication system but it produces intra-channel non-linear effect [10] thus RZ format is meritious as it allows passive optical interleaving to higher bit rates, less immunity to nonlinearities and dispersion which makes this modulation format a feasible solution in long distance transmission. In [11], the link performance employing series of ten EDFA for various formats has been investigated and results conclude that NRZ raised cosine has wider eye opening but as this link consist of number of amplifiers which increases system cost. The DWDM link performance composed of combination of EDFA and RAMAN amplifier has been evaluated for different formats [12] and result reveals that RZ provides less BER. This paper presents a comparison of the performance of NRZ, RZ, Sine and Hyperbolic secant modulation format. The results reveal that the RZ modulation format is compatible with the existing communication network as it provides high Q-Factor and minimum BER.

III. SIMULATION SETUP

The simulation setup of SOA based RoF system used to evaluate and compare the performance of NRZ, RZ, Sine and Hyperbolic secant modulation formats is depicted in Fig. 1. The simulation parameter employed in this RoF system is listed in Table 1.

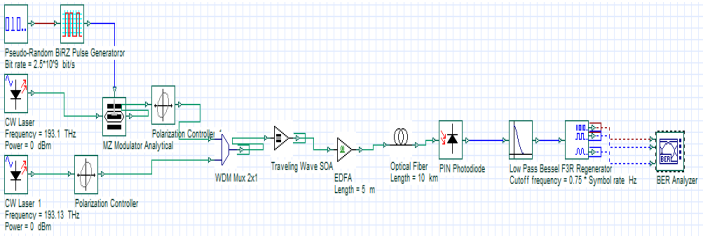


Figure 1. Simulation Setup

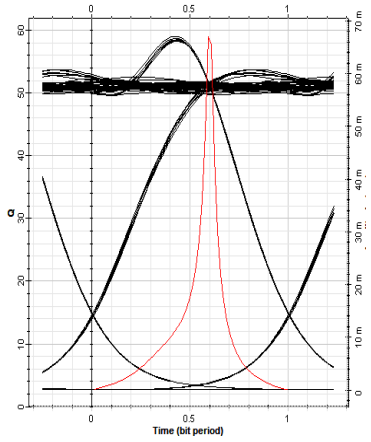
Table 1. Simulation Parameters

Parameter	Specifications
CW Laser Diode 1	193.1 THz
CW Laser Diode 2	193.13 THz
SOA Length	500 µm
SOA Width	3 µm
SOA Height	0.08 µm
EDFA Length	5 m
EDFA Forward Pump Power	100 mW
Bit rate	2.5 Gbps
Fiber Dispersion	16.75 ps/nm-km
Fiber Attenuation	0.2 dB/km
Fiber Length	10 to 50 km

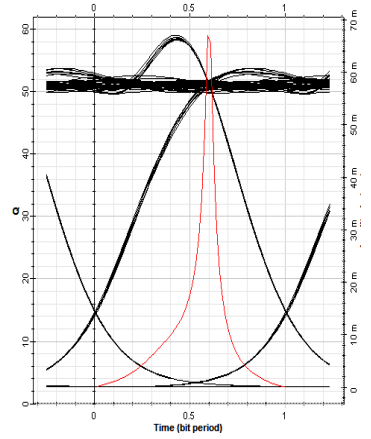
In the downlink transmission, central station generates two signals i.e. light signal and pump signal. Light signal is generated by continuous wave laser diode modulated at 2.5 Gbps using various modulation formats employing MZM. Pump signal is generated by CW laser transmitting at 193.13THz at power level of 0 dBm. These two signals are applied to WDM via polarization controller. The multiplexed optical signal is amplified by SOA followed by EDFA (Erbium doped fiber amplifier). The amplified signal is fed to the photodetector to detect the transmitted signal. The recovered electrical signal is filtered by low pass Bessel filter. The filtered electrical signal has been analyzed using Eye Diagram and BER analyzer.

IV. RESULTS & DISCUSSION

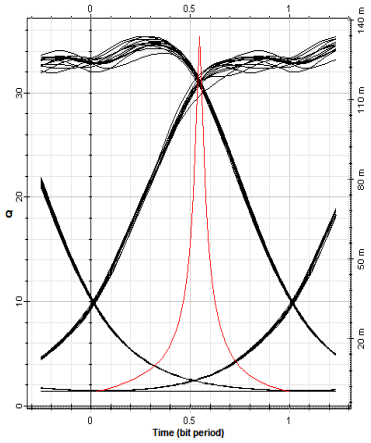
Fig. 2(a-d) exhibit the simulated modulation formats eye diagram generated by 2.5 Gbps PRBS signal. The various performance measures are BER, Q-factor, Eye Diagram and Eye height. The BER defines as the probability of inaccurate recognition of a bit in the receiver and Q-Factor measures the quality of the transmission of signals in terms of its signal-to-noise ratio (SNR), higher the value of Q-factor the better the SNR and therefore the lower the probability of bit errors. The waveform distortion effects can be shown immediately on an oscilloscope by allowing eye diagram measurements in the time domain [10].



(a)



(b)



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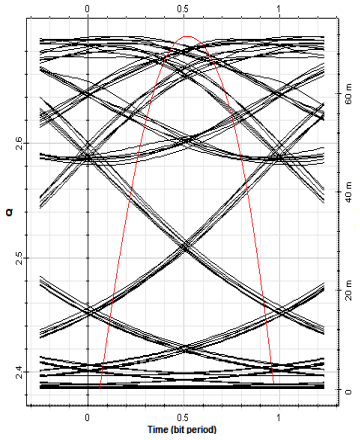

(d)

Figure 2. Eye Diagram of SOA based RoF system at 20km employing (a) NRZ, (b) RZ, (c) Sine and (d)Hyperbolic Secant Pulse Generator Modulation Format

Figure 2(b) shows that the eye diagram is clear and completely opened as comparison to results obtained in the Fig. 2 (a), (c) and (d).

Table 2. Performance of NRZ at various Fiber Length

Fiber Length (km)	10	20	30	40	50
Q-Factor	30.79	59.03	20.46	13.09	12.22
BER	$1.22e^{-208}$	0	$1.46e^{-93}$	$9.13e^{-40}$	$8.21e^{-35}$
Eye-Height	0.0806	0.0544	0.0313	0.018	0.0112

Table 3. Performance of RZ at various Fiber Length

Fiber Length (km)	10	20	30	40	50
Q-Factor	73.58	64.16	15.97	15.96	13.47
BER	0	0	$7.44e^{-58}$	$9.68e^{-58}$	$4.48e^{-42}$
Eye-Height	0.176	0.1223	0.085	0.051	0.0236

Table 4. Performance of Sine Modulation Format at various Fiber Length

Fiber Length (km)	10	20	30	40	50
Q-Factor	34.07	35.42	25.54	13.64	14.86
BER	$1.01e^{-254}$	$3.169e^{-275}$	$1.783e^{-144}$	$6.58e^{-43}$	$9.53e^{-51}$
Eye-Height	0.149	0.105	0.0700	0.063	0.0429

Table 5. Performance of Hyperbolic secant Modulation Format at various Fiber Length

Fiber Length (km)	10	20	30	40	50
Q-Factor	2.83	2.69	2.99	2.903	3.53
BER	0.0015	0.002	0.0012	0.015	0.0002
Eye-Height	-0.0046	-0.0057	$-4.67e^{-5}$	-0.00076	0.0024

Table 2(a-d) reveals the Q-Factor, BER and Eye Height values at various fiber length for different modulation formats. The Q-factor using NRZ, RZ, Sine and Hyperbolic secant modulation formats at 20km length are 59.03, 64.16, 35.42 and 2.69 respectively.

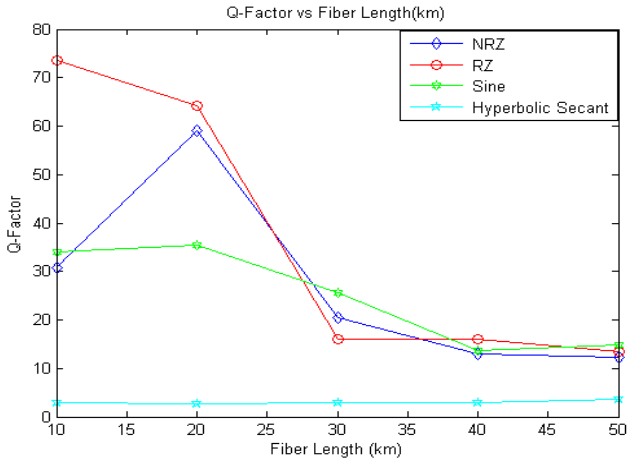

Figure 3. Q-Factor vs Fiber Length (km).

In Fig. 3 Q-factor versus fiber length has been analyzed for different modulation formats and it reveals that Q-factor is more in case of RZ format. Therefore, RZ modulation format can be employed for large propagation distance.

V. CONCLUSION

The modulation formats plays vital role in link design as it reduces the non-linear transmission effects. In this paper,

the impact of various modulation formats i.e. RZ, NRZ, Sine, Hyperbolic Secant over Q-Factor, BER and eye height has been investigated using SOA based RoF system. The simulation results reveal that RZ modulation is found to be the feasible format for transmission of signal over long distance as it has high Q–factor and less BER. Still the RZ format suffers the impairments caused by dispersion but less as compared to other formats thus the dispersion compensation techniques must be incorporated with RZ modulation format for reducing the dispersion effect as well as to transmit high data rate signal in the range of hundred Gbps.

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