SIMULATIVE INVESTIGATION OF SINGLE-TONE ROF SYSTEM USING VARIOUS DUOBINARY MODULATION FORMATS

Namita Kathpal[1] and Amit Kumar Garg[2]

[1,2] Department of Electronics & Communication Engineering,
Deenbandhu Chhotu Ram University of Science & Technology, India.

ABSTRACT

In this paper, the performance of single-tone Radio over Fiber (RoF) system has been analyzed by employing different duobinary modulation formats. This single-tone RoF system has been modeled and analyzed using OptiSystem (14.0) software. To evaluate the transmission performance of RoF system, various performance metrics such as Q-factor, BER, and Eye Height are considered. Simulation results indicate that duobinary Hyperbolic-Secant pulse generator format with Single Drive Mach-Zehnder modulator provides better Q-factor and minimum BER as compared to existing modulation format in RoF system.

KEYWORDS

Duobinary NRZ, Duobinary RZ, Single Drive Mach-Zehnder Modulator, Duobinary Gaussian pulse generator; Duobinary Hyperbolic-secant pulse generator

1. INTRODUCTION

The exponential increasing bandwidth demand for high-speed wireless access requires the combination of wireless technology and fiber access technology [1]. Radio over Fiber is considered to be a possible solution in providing broadband wireless access services in the emerging optical wireless networks [2]. RoF uses analog optical transmission links and is used extensively for distributed antenna system deployments around the world [3]. RoF system performance depends on various factors such as modulation format, optical modulation, electrical modulation, optical fiber, optical source power level, bit rate and an optical detector. Duobinary modulation format has been used efficiently in RoF system since the duobinary signals provide higher spectral efficiency by reducing the signal bandwidth by transmitting two successive bits in the digital bit stream [4].

DB also provides higher chromatic dispersion tolerance which reduces the need for the dispersion compensation technique [5]. MD-RZ modulation format has been analyzed using symmetrical dispersion compensation technique which improves the system performance but reduces the transmitted optical power [6]. The optical DPSK and DB formats have been combined to provide 40Gb/s signal transmission but this combined modulation format increased dispersion in long reach WDM- Passive Optical Networks [7]. DB format can be implemented using single drive MZM, provided high Q-factor and the channel spacing matches the interferometer free-spectral range [8-9]. In this paper, the single-tone RoF system using various DB modulation formats has been modulated using single drive MZM and the performance of various DB modulation format in terms of Q-factor, BER, and eye height has been compared.

2. SIMULATION SETUP

The simulation setup is shown in Fig. 1 used to analyze and compare the performance DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant pulse generator modulation formats. In the transmitter section, pseudo random bit sequence generator (PRBS) generates data signal which is modulated by employing single drive MZM using DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant pulse generator modulation formats over a continuous wave laser biased at 193.1THz with a line width of 10MHz. The modulated optical signal is transmitted over an optical fiber of length varying from 10km to 50km and amplified by EDFA. In the receiver section, the amplified optical signal is detected by PIN photodetector and detected electrical signal is filtered and analyzed by BER analyzer.

Table 1. Simulation Parameters.

Layout Parameters	**Value**
Bit Rate	1Gbps to 15Gbps
Sequence Length	128bits
Samples per bit	64
Number of Samples	8192
Sensitivity	-100dBm
Resolution	0.1nm
Transmitter Parameters	**Value**
PRBS Bit Rate	1Gbps to 15Gbps
Duobinary Precoder Delay	1bit
CW Laser Power	0dBm
CW Laser Frequency	193.1THz
CW Laser Linewidth	10MHz
Single Drive MZM Parameters	**Value**
Splitting Ratio	1.3
Bias Voltage1	-2.8V
Bias Voltage2	-1.1V
Modulation Voltage	1.5V
SMF Parameters	**Value**
Length	10km to 50km
Attenuation	0.2dB/km
Dispersion	16ps/nm-km
Dispersion Slope	0.075
Effective Area	$80\mu m^2$
Differential Group Delay	0.2ps/km
EDFA Parameters	**Value**
Length	5m
Forward Pump Power	100mW
Backward Pump Power	0mW
Forward Pump Wavelength	980nm
Backward Pump Wavelength	980nm
Receiver Parameters	**Value**
PIN Responsivity	1A/W
Dark Current	10nA
Thermal Noise	10^{-22}W/Hz

Low Pass Bessel Filter cut off frequency	0.75 * Bit Rate Hz
Low Pass Bessel Filter Insertion Loss	0dB
Low Pass Bessel Filter Order	4

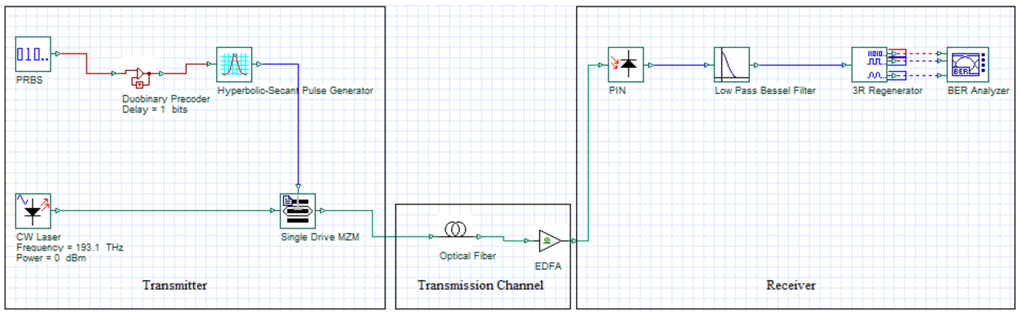


Figure 1. Simulation Setup of single-tone RoF system employing different duobinary modulation format.

3. Results and Discussion

Fig. 2 shows the eye diagrams for various duobinary modulation formats for single tone RoF system. It is observed that eye pattern is clearly opened in case of DB-Hyperbolic secant pulse generator modulation format and shown in Fig. 2(d).

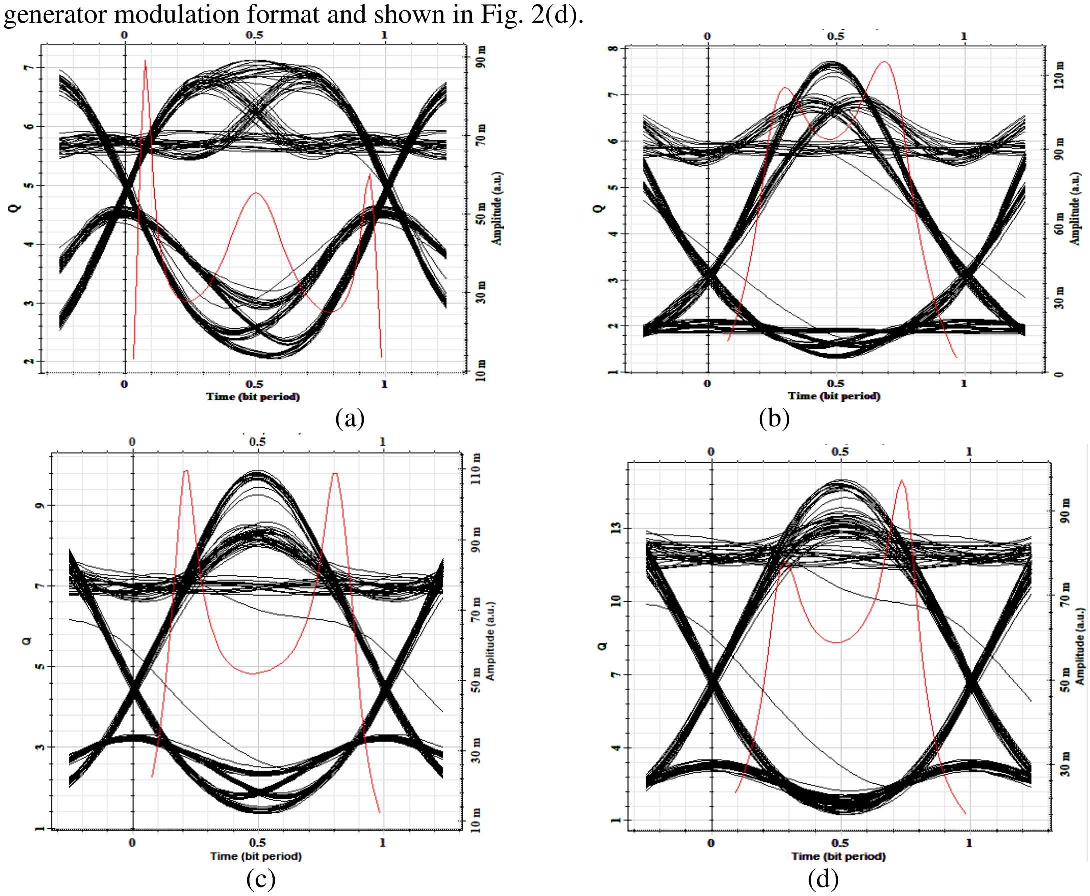


Figure 2 Eye Diagram of single-tone RoF system with (a) DB-RZ, (b) DB-NRZ, (c) DB-Gaussian, (d) DB-Hyperbolic secant modulation formats at 20km fiber length for 15Gbps bit rate.

Table 2. Performance of DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant Modulation Format at various Fiber Length at 1Gbps.

Fiber Length (km)	DB-RZ			DB-NRZ			DB-Gaussian			DB-Hyperbolic Secant		
	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height
10	199.91	Zero	0.046	585.7	Zero	0.075	72.95	Zero	0.054	11.41	$1.76e^{-30}$	0.039
20	179.50	Zero	0.045	401.2	Zero	0.072	73.84	Zero	0.053	11.45	$1.07e^{-30}$	0.038
30	177.39	Zero	0.043	366.2	Zero	0.069	72.99	Zero	0.050	11.47	$8.64e^{-31}$	0.037
40	142.53	Zero	0.041	253.9	Zero	0.063	73.50	Zero	0.047	11.56	$3.01e^{-31}$	0.034
50	131.84	Zero	0.037	207.5	Zero	0.057	68.83	Zero	0.043	11.48	$7.70e^{-31}$	0.031

Table 3. Performance of DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant Modulation Format at various Fiber Length at 5Gbps.

Fiber Length (km)	DB-RZ			DB-NRZ			DB-Gaussian			DB-Hyperbolic Secant		
	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height
10	93.57	Zero	0.048	96.68	Zero	0.073	82.69	Zero	0.056	12.73	$1.83e^{-37}$	0.042
20	53.16	Zero	0.047	54.68	Zero	0.069	62.73	Zero	0.055	14.08	$2.18e^{-45}$	0.043
30	39.83	Zero	0.045	42.10	Zero	0.065	46.38	Zero	0.052	15.81	$1.16e^{-56}$	0.043
40	32.32	$1.47e^{-229}$	0.042	33.93	$1.10e^{-252}$	0.059	31.86	$3.17e^{-223}$	0.049	16.79	$1.38e^{-63}$	0.041
50	28.05	$1.94e^{-173}$	0.039	29.11	$9.99e^{-187}$	0.052	24.09	$1.32e^{-128}$	0.044	18.61	$1.21e^{-77}$	0.039

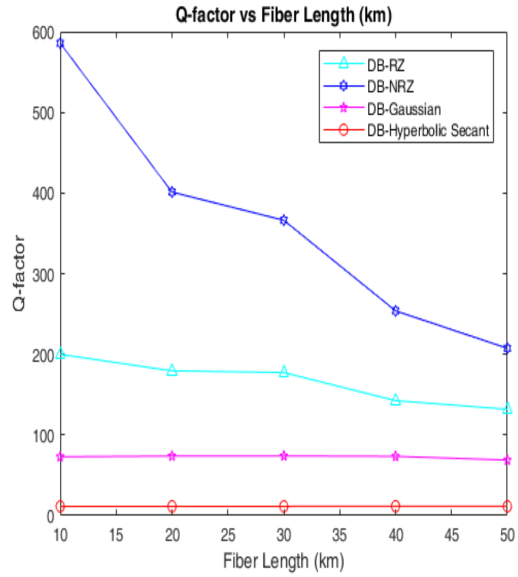
Table 4. Performance of DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant Modulation Format at various Fiber Length at 10Gbps.

Fiber Length (km)	DB-RZ			DB-NRZ			DB-Gaussian			DB-Hyperbolic Secant		
	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height
10	42.20	Zero	0.049	40.38	Zero	0.070	37.45	$2.42e^{-307}$	0.057	18.79	$3.78e^{-79}$	0.049
20	21.80	$1.15e^{-105}$	0.047	29.65	$1.48e^{-193}$	0.065	17.19	$1.26e^{-66}$	0.051	24.24	$4.15e^{-130}$	0.052
30	10.82	$1.33e^{-27}$	0.038	13.75	$2.11e^{-43}$	0.056	12.25	$7.96e^{-35}$	0.041	15.92	$1.95e^{-57}$	0.048
40	6.48	$4.42e^{-11}$	0.027	8.96	$1.32e^{-19}$	0.047	9.68	$1.79e^{-22}$	0.031	13.51	$5.27e^{-42}$	0.039
50	5.99	$1.00e^{-9}$	0.010	6.63	$1.32e^{-11}$	0.038	7.86	$1.83e^{-15}$	0.026	10.99	$1.58e^{-28}$	0.033

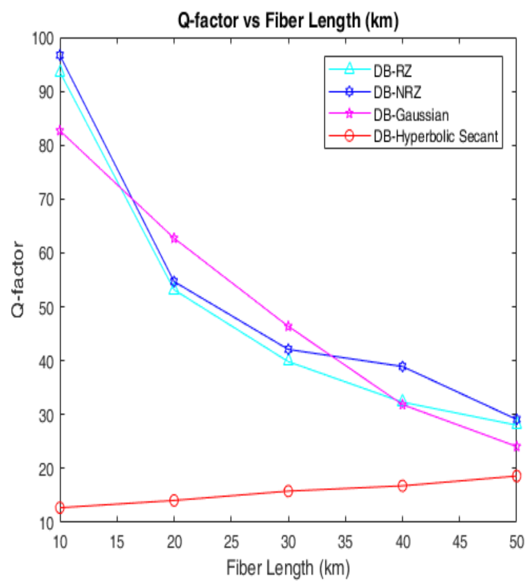
Table 5. Performance of DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant Modulation Format at various Fiber Length at 15Gbps.

Fiber Length (km)	DB-RZ			DB-NRZ			DB-Gaussian			DB-Hyperbolic Secant		
	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height	Q-factor	BER	Eye Height
10	19.19	$2.23e^{-82}$	0.048	28.58	$5.9e^{-180}$	0.068	19.79	$1.44e^{-87}$	0.051	24.13	$5.24e^{-129}$	0.054
20	7.12	$5.2e^{-13}$	0.02	7.72	$4.3e^{-15}$	0.051	9.86	$2.88e^{-23}$	0.035	14.99	$3.02e^{-51}$	0.045
30	2.17	0.01	-0.02	7.13	$4.8e^{-13}$	0.05	5.40	$2.81e^{-8}$	0.023	7.30	$9.6e^{-14}$	0.032
40	2.20	0.01	-0.02	4.02	$6.8e^{-10}$	0.037	3.26	0.0004	0.004	4.37	$5.46e^{-6}$	0.017
50	2.02	0.02	-0.018	4.58	$2.13e^{-6}$	0.02	2.91	0.0017	-0.0014	4.53	$2.78e^{-6}$	0.016

Table 2-5 summarizes the value of various performance metrics for single tone RoF system with different duobinary modulation formats. At 1Gbps and 5Gbps bit rate, DB-NRZ provides the maximum Q-factor at various fiber length as shown in Table 2 and Table 3.


Q-factor vs Fiber Length (km)
Q-factor
Fiber Length (km)
DB-RZ
DB-NRZ
DB-Gaussian
DB-Hyperbolic Secant
0
100
200
300
400
500
600
10
15
20
25
30
35
40
45
50

(a)


Q-factor vs Fiber Length (km)
Q-factor
Fiber Length (km)
DB-RZ
DB-NRZ
DB-Gaussian
DB-Hyperbolic Secant
10
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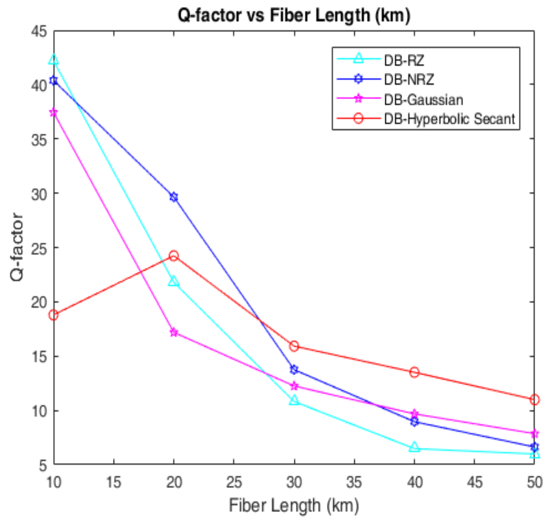
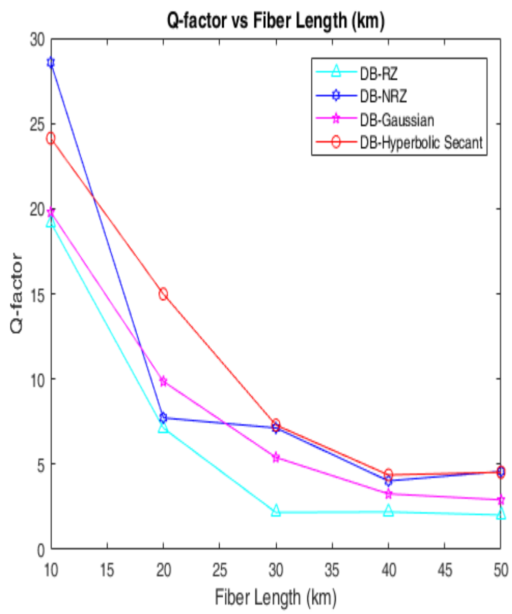
(b)



(c)



(d)

Figure 3 Q-Factor vs Fiber Length (km) at (a) 1Gbps, (b) 5Gbps, (c) 10Gbps and (d) 15Gbps.

Based on the result achieved in Table 4, it is seen that at 10Gbps, DB-NRZ, DB-RZ and DB-Gaussian pulse generator provides high Q-factor at small fiber length whereas DB-Hyperbolic secant pulse generator performs best at 50km fiber length.The Q-factor with the DB-Hyperbolic secant pulse generator modulation format is calculated as 14.99 and reduced to 9.86 using DB-Gaussian modulation format, which again reduces to 7.72 using DB-NRZ format, which is further, reduces to 7.12 in the case of DBRZ format at 15Gbps for 20km fiber length as shown in Table 5. It is also observed from Fig. 2 (a-d) and Table 3-5 that BER reduces more by using DB-Hyperbolic secant pulse generator modulation format at high bit rate for long transmission distance.

In Fig. 3 Q-factor versus fiber length at various bit rate has been analyzed for different modulation formats. Fig. 3 (a) and Fig. 3 (b) reveals that both DB-RZ and DB-NRZ have high Q-factor for low bit rates i.e. 1Gbps and 5Gbps but when bit rate is increased, as shown in Fig. 3 (c) and Fig. 3 (d) both DB-RZ and DB-NRZ shows a rapid decrease in Q-factor. Thus, from the simulation results obtained, it is concluded that Q-factor is more in case of hyperbolic secant pulse modulation format at 15Gbps for long transmission distance as shown in Fig. 3 (d).

4. CONCLUSIONS

The performance of DB-RZ, DB-NRZ, DB-Gaussian and DB-Hyperbolic secant pulse generator modulation formats has been analyzed in terms of the eye diagram, Q-factor, and BER for single tone RoF system. Simulation result indicates that DB-Hyperbolic secant pulse generator modulation format works efficiently as it provides high Q-factor, less BER and maximum eye opening for longer transmission distance as compared to other DB modulation formats at 15Gbps. Thus DB-Hyperbolic secant pulse generator modulation format is the practical solution for long haul RoF communication system.

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