Performance Comparison Of Dd-Dpsk-Ofdm And Co-Dpsk-Ofdm In Isowc Systems

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Abstract- In this work, an intersatellite optical wireless system at 10 Gbps is proposed using coherent optical differential phase shift keying based orthogonal frequency division multiplexing. For the investigation of the proposed system, different parameters are taken into consideration such as different distances, pointing errors, diverse power levels and results are observed in terms of signal to noise ratio, Q factor and BER. Further, work is extended to check the performance of 850 nm and 1550 nm in the proposed system to find optimal wavelength window for the operation.

Keywords - BER, CO-DPSK-OFDM, DD-DPSK-OFDM, IsOWC, Q factor, SNR, Pointing errors

Introduction

Optical wireless communication using laser technology in space is getting attention because of the ever increasing demands and its advantages over radio frequency communication [1]. Intersatellite optical wireless communication has high capacity systems, high speed channels, secure communication, unlicensed operations, absence of electromagnetic interferences, and long distance transmission as compared to RF communication and therefore optical communication replacing it in space [2]. Relay communication in IsOWC is taken as biggest application because it eliminated the inclusion of requirement of ground station every time [3]. Intersatellite optical wireless communication is utmost area of research due the participation of different countries in space and day by day satellites in space are increasing. Satellite revolves around earth and the heavenly area where these satellites are employed is termed as orbits. Lower earth orbits are 100 km to 5000 km above the earth surface and shape of the orbit is circular. This orbit is not stationary and takes 2-4 hours to complete one round around earth. Medium earth orbit are 5000 km to 25000 km above the earth surface with 4-12 hours time to complete one round and Geosynchronous Earth Orbits have identical speed as earth rotates therefore it seems that they are stationary. These orbits are 35786 km above the earth surface and orbit time is 24 hours [4]. The main ambition of most upcoming wireless communications techniques is to get highest results in the given bandwidth with minimum amount of errors. Orthogonal Frequency Division Multiplexing (OFDM) is a very often applied modulation approach [5]. OFDM bears resistance to frequency selective fading than any single carrier system do, because it splits the entire channel into various signals of a narrowband that get affected individually as flat fading sub-channels. OFDM also have Resilience to interference, Spectrum efficiency, [6] Resilient to “inter symbol interference”, and support high data rates [7]. Recently, direct detection differential phase shift keying based optical wireless system is reported [8]. Enhancement of demonstrated IsOWC systems is required because pointing error vanish the communication. In this work, a performance enhanced coherent optical differential phase shift keying based optical wireless system is proposed at 10 Gbps for 20000 km.

System setup

For the realization of the proposed intersatellite optical wireless system using coherent optical differential phase shift keying based orthogonal frequency division multiplexing, optisystem simulation software is considered due to its features as well as easy graphical user interface. Figure 1 represents the proposed system of single channel CO-DPSK-OFDM in IsOWC at 10 Gbps. A binary data generator at 10 Gbps for generating binary data streams of ones and zeros is placed at the start of communication and pseudo random bit sequence generator is the component used for it in the simulation. Serial data stream from the PRBS then passed through 4-DPSK encoder which is employed here to change serial bit stream into parallel bit stream. Parallel binary signals then fed into orthogonal frequency division modulator where orthogonal frequencies are mixed with this data. OFDM modulator has 512 subcarriers and 1024 number of inverse fast fourier points.

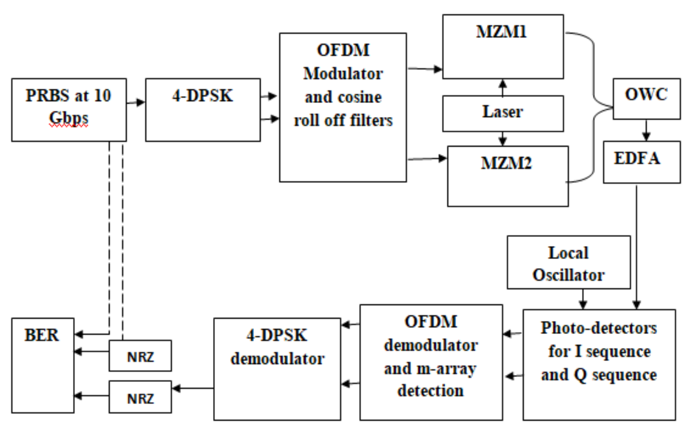

Fig. 1. Proposed CO-DPSK-OFDM intersatellite optical wireless system

Here cyclic prefix are considered to reduce the intercarrier interference. Real and imaginary signals from the OFDM

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modulator then communicated to low pass cosine roll off filters to shape the data and to remove the noises. These lowpass cosine roll off filters are followed by the electrical amplifier and mach zehnder modulator. MZM modulator are placed to convert the electrical signal into optical domain by taking the reference of CW laser. CW laser has frequency of 193.1 THz (1550 nm) and power of -4 dBm. Drive of laser is divided into halfs and each one is coupled to the MZM1 and MZM2. Power combiner does the task of joining output of two MZMs and combined signal is fed to the transmission module. Transmission module consists of intersatellite optical wireless channel and erbium doped fiber amplifier. Optical wireless channel has different parameters such as antenna sizes of transmitter and receiver, pointing errors, attenuation and link length. Antenna aperture radius is fixed at 15 cm for both transmitter and receiver. Mathematically received signal in IsOWC is represented as $P_R = P_T\eta_T\eta_R(\frac{P_R}{4\prod z})^2 G_T G_R L_T L_R$ where PT is the transmitter optical power, η_T is the optics efficiency of the transmitter, η_R is the optics efficiency of the receiver, λ is the wavelength, Z is the distance between the transmitter and the receiver given by the parameter Range, G_T is the transmitter telescope gain, G_R is the receiver telescope gain, L_T and , L_R are the transmitter and the receiver pointing loss factor, respectively. Loss factor with the pointing errors is: $L_T = \exp(-G_T\theta_T^2)$ Where θ_T is azimuth pointing error angle of transmitter and receiver pointing errors are given as $L_R = \exp(-G_T\theta_R^2)$ where, θR is the receiver azimuth pointing error.

TABLE 1
System specifications of the proposed system

Parameter	Values
Data rate	10 Gbps
Modulation	CO-DPSK-OFDM
OWC length	5000 km-20000 km
Pointing errors	1 μrad-5 μrad
OWC transmitter antenna	15cm
OWC receiver antenna	15 cm
Wavelengths	850 nm, 1550 nm
Amplifier	EDFA
Photodetectors	PIN

Further an optical amplifier with 5 dB Gain and 4 dB noise figure is placed to increase the power level of transmitted signal. Further signal is sent to receiver module which consists of 4 photodetectors i.e. PIN and local oscillator. Function of local oscillator is to match phase of the received signal with the transmitted signal. Imaginary and real sequence are detected with the help of local oscillator and phase shifter in the receiver. Further fast fourier transform in order to extract orthogonal frequencies is done at OFDM demodulator. M-array has significance to detect pulse levels and constellation analyzer is connected to it for showing the error vector magnitude. Table 1 shows the system specification of the proposed system. This parallel bit streams then given to 4-DPSK demodulator which does the task of converting parallel to serial bit streams. In order to get the eye diagram of the proposed system, three signals are connected to BER analyzer such as reference of PRBS, reference of NRZ and received signal after passive through NRZ.

RESULTS AND DISCUSSIONS

Performance of single channel intersatellite optical wireless system at 10 Gbps using coherent optical differential phase shift keying based orthogonal frequency division multiplexing is investigated in this work at different distances, pointing errors in terms of signal to noise ratio, Q factor and BER. Error vector magnitude is analyzed from the constellation analyzer in case of different distances and receiver pointing errors. Distance enhancement in intersatellite optical wireless communication is an utmost work and in order to check the performance of proposed CO-DPSK-OFDM system, distance of optical wireless channel is varied from 1000 km to 20000 km and effects of link length increase are observed on the signal to noise ratio. Moreover, direct detection DPSK-OFDM is also compared with the proposed scheme as shown in Figure 2.

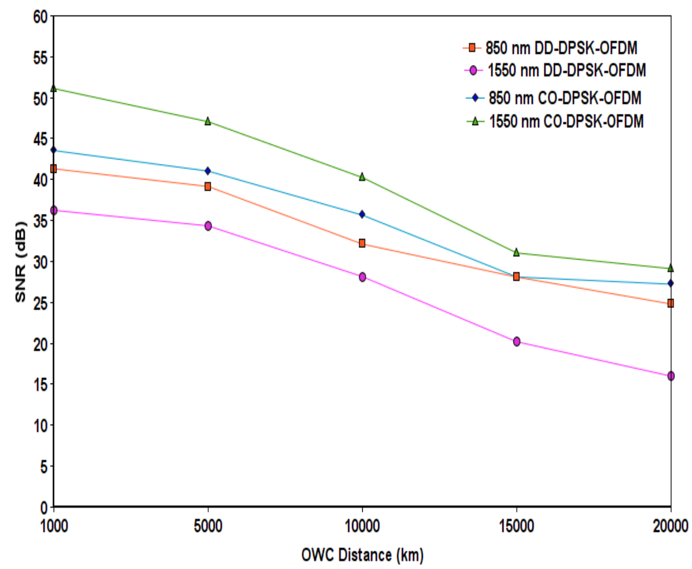
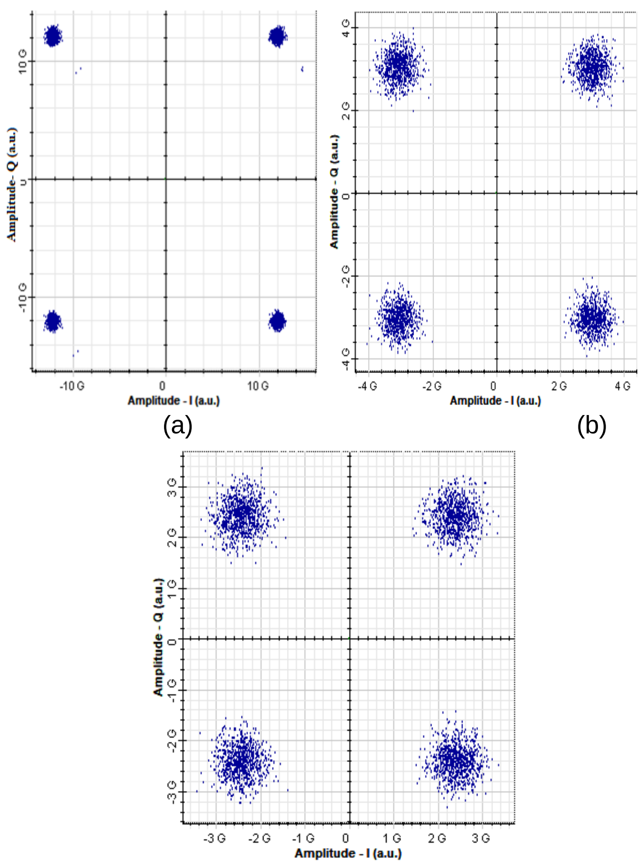


Fig. 2. *Comparison of DD-DPSK-OFDM and CO-DPSK-OFDM at different distance in proposed system*

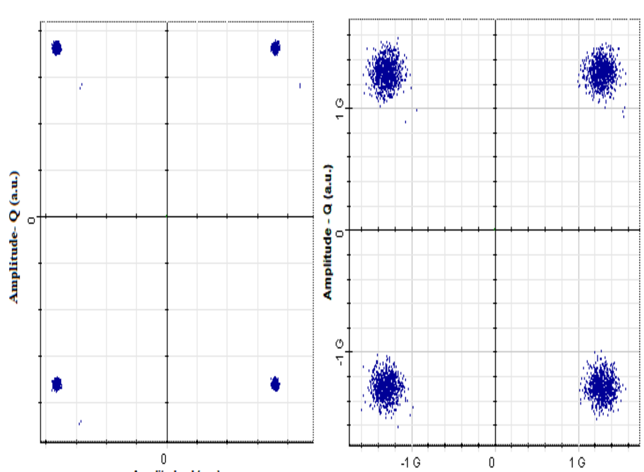
Results revealed that there is decrease in the signal to noise ratio as the distance prolongs because of the attenuation, dispersion and scattering effects. In order to cope up with the issues of signal degradation, erbium doped fiber amplifier is deployed but SNR decreases because of noise emergence. In this comparison, 850 nm, 1550 nm DD-DPSK-OFDM system is compared with 850 nm, 1550 nm CO-DPSK-OFDM. It is perceived that SNR decreases in both the cases but there is highest SNR in case of 1550 nm wavelength based on CO-DPSK-OFDM because EDFA amplifier works very well in conventional band and due to presence of local oscillator in the coherent DPSK-OFDM, performance of the system increases. Figure 3 represents the constellation diagrams of proposed CO-DPSK-OFDM system for 850 nm at different distances such as 5000 km, 16250 km and 20000 km. It is observed that error vector magnitude increases with the increase in the distance and minimum EVM is seen at 5000 km and maximum at 20000 km. Figure 4 represents the constellation diagrams of proposed CO-DPSK-OFDM system for 1550 nm at different distances such as 5000 km, 16250 km and 20000 km. It is observed that error vector magnitude increases with the increase in the distance and minimum EVM is seen at 5000 km and maximum at 20000 km. However EVM is far lesser in 1550 nm than 850 nm due to EDFA.



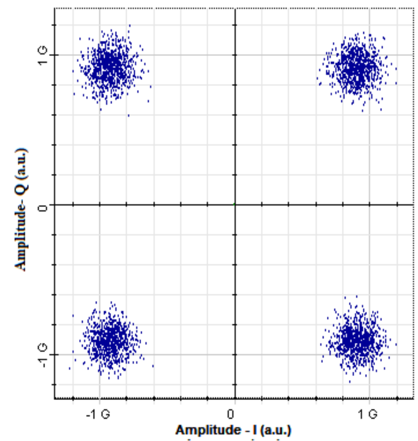
(a) (b)

(c)

Fig. 3. *Constellation diagrams at (a) 5000 km (b) 16250 km (c) 20000 km for 850 nm*



(a) (b)



(c)

Fig. 4. Constellation diagrams at (a) 5000 km (b) 16250 km (c) 20000 km for 1550 nm

Figure 5 represents the comparison of DD-DPSK-OFDM and CO-DPSK-OFDM in intersatellite optical wireless system at different distances in terms of Q factor. In this comparison, 850 nm, 1550 nm DD-DPSK-OFDM system is compared with 850 nm, 1550 nm CO-DPSK-OFDM. It is perceived that Q factor decreases in both the cases but there is highest Q factor in case of 1550 nm wavelength based on CO-DPSK-OFDM because EDFA amplifier provide high gain in conventional band and due to presence of local oscillator in the coherent DPSK-OFDM, performance of the system increases. Further investigation is carried out to measure bit error rate of DD-DPSK-OFDM and CO-DPSK-OFDM at different link lengths. It is perceived from the Table 2 that as the link length prolongs, there is increase in BER.

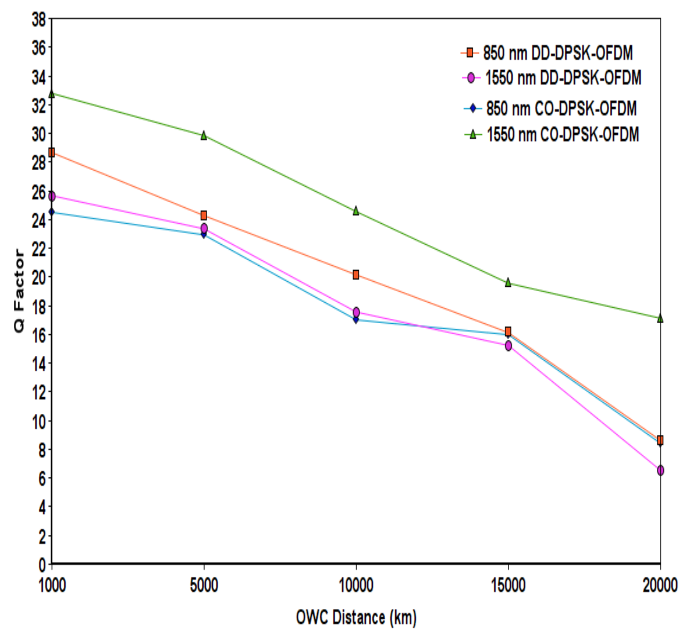


Fig. 5. Comparison of DD-DPSK-OFDM and CO-DPSK-OFDM in terms of Q factor

TABLE 2
VALUES OF BER AT DIFFERENT DISTANCES FOR DD-DPSK-OFDM AND CO-DPSK-OFDM

Distance (km)	850 nm DD-DPSK-OFDM	1550 nm DD-DPSK-OFDM	850 nm CO-DPSK-OFDM	1550 nm CO-DPSK-OFDM
1000	$1.2*10^{-172}$	$1.2*10^{-156}$	$1.2*10^{-148}$	$5.6*10^{-212}$
5000	$3.5*10^{-135}$	$3.5*10^{-121}$	$3.5*10^{-116}$	$5.6*10^{-196}$
10000	$1.4*10^{-120}$	$1.4*10^{-108}$	$1.4*10^{-102}$	$2.1*10^{-144}$
15000	$5.1*10^{-85}$	$5.1*10^{-75}$	$5.1*10^{-77}$	$4.3*10^{-101}$
20000	$6.4*10^{-18}$	$6.4*10^{-11}$	$6.4*10^{-17}$	$5.17*10^{-66}$

Figure 6 represents the performance of DD-DPSK-OFDM and CO-DPSK-OFDM in terms of SNR at different launched power levels such as -4 dBm and 10 dBm for receiver pointing errors. It is observed that increase in the receiver pointing errors leads to the performance degradation in both DD-DPSK-OFDM and CO-DPSK-OFDM. However it is perceived that high input power such as 10 dBm in case of CO-DPSK-OFDM performs best and followed by the performance of -4 dBm because of the phase matching and EDFA amplification. Effect of input power in both cases brings better SNR when it is set to 10 dBm. Increase in the SNR for increase power level is quite obvious because nominator of the signal to noise ratio and in turns it increases.

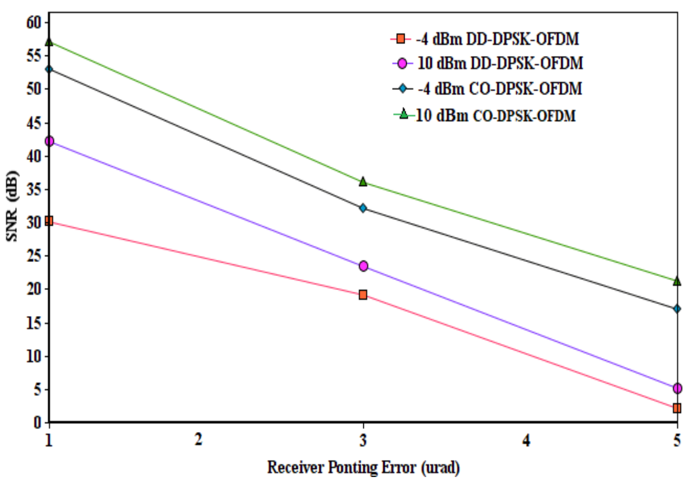
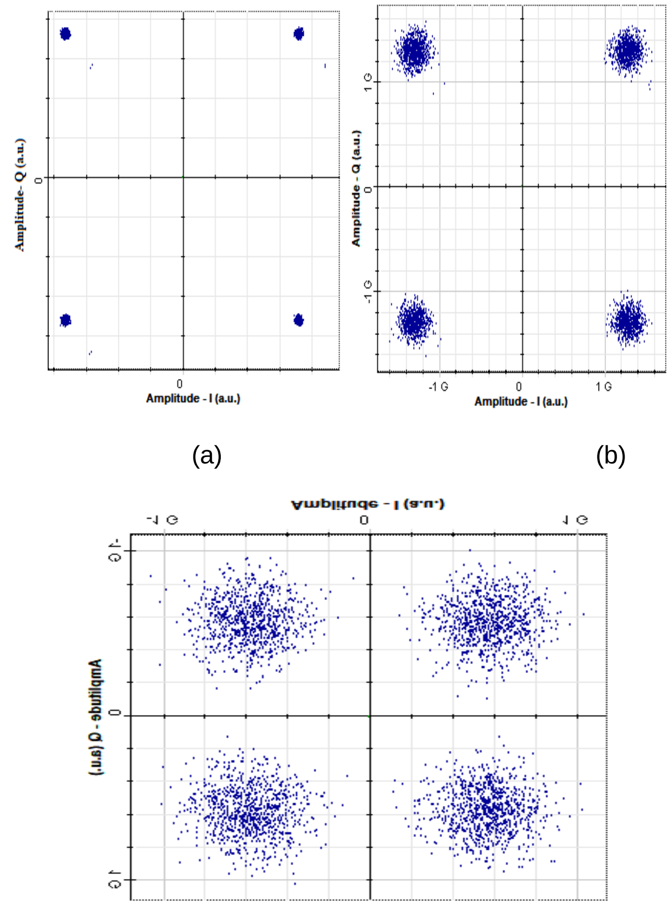


Fig. 6. Effect of receiver pointing errors on SNR

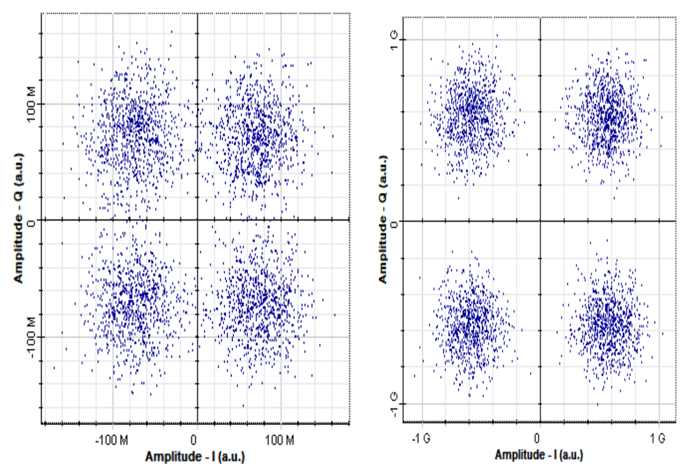
Further in Figure 7, constellations of the CO-DPSK-OFDM at 1 µrad, 3 µrad and 5 µrad are represented. There is very low and sharp pointy error vector magnitude for 1 µrad receiver pointing error and as the pointing error approaches to 3 µrad, there is increase in error vector magnitude. . Highest EVM is observed in case of 5 µrad where signal is deviated from its original position.



(a) (b)

(c)

Fig. 7. Constellation at receiver pointing errors (a) 1 µrad (b) 3 µrad (c) 5 µrad for CO-DPSK-OFDM



(a) (b)

Fig. 8. Constellation diagram at (a) -4 dB (b) 10 dB input power for 1550 nm CO-DPSK-OFDM

At 10000 km link distance of intersatellite optical wireless communication, constellations at 10 dBm input power and -4 dBm input power are depicted in Figure 8. It is clearly observed that more power brings less error vector magnitude and therefore constellation is better at 10 dBm input power as compared to -4 dBm input power. In existing work, a 10 Gbps direct detection differential phase shift keying based OFDM system was investigated for different distances and wavelengths [8]. In proposed work coherent optical DPSK-OFDM is used where local oscillator is present for phase matching at 10 Gbps. Semiconductor optical amplifier was used in existing work and EDFA is used in proposed work. Table 3 represents the comparison of proposed work and existing work in terms of SNR.

TABLE 3
COMPARISON OF EXISTING WORK WITH PROPOSED WORK

Parameters	Existing work	Proposed work
Data rate	10 Gbps	10 Gbps
Modulation	Direct detection DPSK-OFDM	Coherent detection DPSK-OFDM
Amplifier	Semiconductor optical amplifier	Erbium doped fiber amplifier
Wavelengths investigated	850 nm, 1550 nm	850 nm, 1550 nm
SNR at 5000 km for 850 nm	39.16 dB	41.04 dB
SNR at 5000 km for 1550 nm	34.35 dB	47.07 dB
SNR at 16250 km for 850 nm	27.70 dB	27.98 dB
SNR at 16250 km for 1550 nm	19.21 dB	30.14 dB
SNR at 20000 km for 850 nm	24.81 dB	27.23 dB
SNR at 20000 km for 1550 nm	16 dB	29.12 dB

CONCLUSION

This research work is focused on the 10 Gbps coherent detection differential phase shift keying orthogonal frequency division multiplexed (CO-DPSK-OFDM) intersatellite optical wireless system. Performance of proposed system is checked at two different wavelengths such as 850 nm and 1550 nm in terms of SNR, Q factor and BER. Different distance and receiver pointing errors are also evaluated in the proposed and proposed system is further compared with DD-DPSK-OFDM. It is perceived that CO-DPSK-OFDM system performed best and 1550 nm found out to be optimal due to presence of EDFA in the link. Moreover effect of receiver pointing error are checked and it is perceived that worst SNR is reported at 5 μrad receiver pointing error and highest on 1 μrad. Effect of input power is also checked and 10 dBm input power offered high SNR as compared to -4 dBm. Proposed system with CO-DPSK-OFDM can cover 20000 km with enhanced SNR as compared to DD-DPSK-OFDM.

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