



Impact of Various Channel Coding Schemes on Performance Analysis of Subcarrier Intensity-Modulated Free Space Optical Communication System

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Abstract: In this paper, we made a comprehensive simulative study on the performance assessment of a Subcarrier intensity-modulated Free Space Optical (FSO) Communication system. The proposed system under investigation consider a communication link between a base station and a mobile unit using light wave transmission through free space in consideration with Atmospheric turbulence effect. The FSO system implements various types of channel coding schemes such as LDPC, Turbo, Cyclic, BCH and Reed-Solomon. From MATLAB based simulated study on synthetic data transmission, it is found a quite noticeable impact on implementing different types of channel coding schemes on performance enhancement of the presently considered FSO system. The system is also capable of showing its robustness in retrieving transmitted data in spite of atmospheric turbulence effect under QAM digital modulation and BCH channel coding scheme.

Keywords: FSO, channel coding, Bit Error rate (BER) and Atmospheric turbulence effect.

I. Introduction

Free-space optical (FSO) communication is an emerging technology which offers license-free spectrum and highly secure link. The Free-space optical (FSO) communication systems are capable of providing high data transmission rates and have received considerable attention during the past few years in many applications linking with satellite communication, fiber backup, RF-wireless back haul and last mile connectivity, unmanned aerial vehicles (UAVs), high altitude platforms (HAPs), aircraft, and other nomadic communication partners. Over the last two decades free-space optical communication (FSO) has become more and more interesting as an adjunct or alternative to radio frequency communication. In high-speed FSO signal detection, Avalanche photodiodes (APD) are normally used where the noise shows signal-dependent Gaussian noise (SDGN) distribution rather than the signal-independent Gaussian noise (SIGN) distribution. It has been known that the FSO communication link availability becomes limited during foggy weather and heavy snow fall. The FSO signal intensity undergoes random fluctuation due to the atmospheric turbulence, known as scintillation. Scintillation causes performance degradation and possible loss of connectivity. These drawbacks pose the main challenge for the FSO communication system deployment. To meet up desire of mitigating such drawbacks and keeping in view of improving FSO system performance, emphasis is given on the various channel coding schemes [1-3].

The FSO communication system utilizes subcarrier intensity modulation which is a technique borrowed from the very successful multiple carrier RF communications already deployed in applications such as digital television, LANs, asymmetric digital subscriber line (ADSL), 4G communication systems and optical fiber communications. In optical fiber communication networks, the subcarrier modulation techniques have been commercially adopted in transmitting cable television signals and have also been used in conjunction with wavelength division multiplexing [4]. The present study is intended to make a comprehensive study on performance assessment of Subcarrier intensity-modulated Free Space Optical Communication system under implementation of various channel coding schemes.

II. Channel Coding

In this paper, the synthetically generated binary data are encrypted. The input binary bit stream is encrypted using symmetric stream cipher [5]. The encrypted binary data are channel encoded using various channel coding schemes such as Cyclic, Reed Solomon, Bose-Chadhuri-Hocquenghem (BCH), LDPC and Turbo. In cyclic coding, the encrypted binary data streams are rearranged into blocks with each block containing two consecutive bits. For each bit, additional redundant identical bit is pre appended to produce cyclically encoded data. In Reed Solomon (RS) nonbinary block coding, 512 information symbols is encoded in a block of 572 symbols. Each information symbol consists of 16 bits and 16 redundant symbols are added at the end of 512 information

symbols to produce a RS block encoded data of 572 symbols. In Bose-Chadhuri-Hocquenghem (BCH) channel coding, the encrypted data are arranged into 64 rows $\times$ 64 columns. Its each 64-elements based row represents a message word and additional 63 parity bits are appended at the end of each message word. The BCH channel encoded data would be 64 rows $\times$ 127 columns [6],[7]. The LDPC and Turbo channel coding schemes have been discussed in details [8],[9].

III. System Description

The block diagram of the simulated Subcarrier intensity-modulated Free Space Optical Communication system is depicted in Figure 1. The synthetically generated binary data are encrypted using symmetric block cipher cryptographic scheme. The encrypted binary data are channel encoded prior to conversion into complex digitally modulated symbols [10]. The real and imaginary part of each complex symbol is multiplied by a carrier represented by cosine wave and its 90 degree phase shifted version. Eventually, all components are summed up and fed into electrical to optical converter. The optically generated signal is passed through atmospheric channel and detected in the receiver. In the receiving section, optical to electrical conversion takes place.

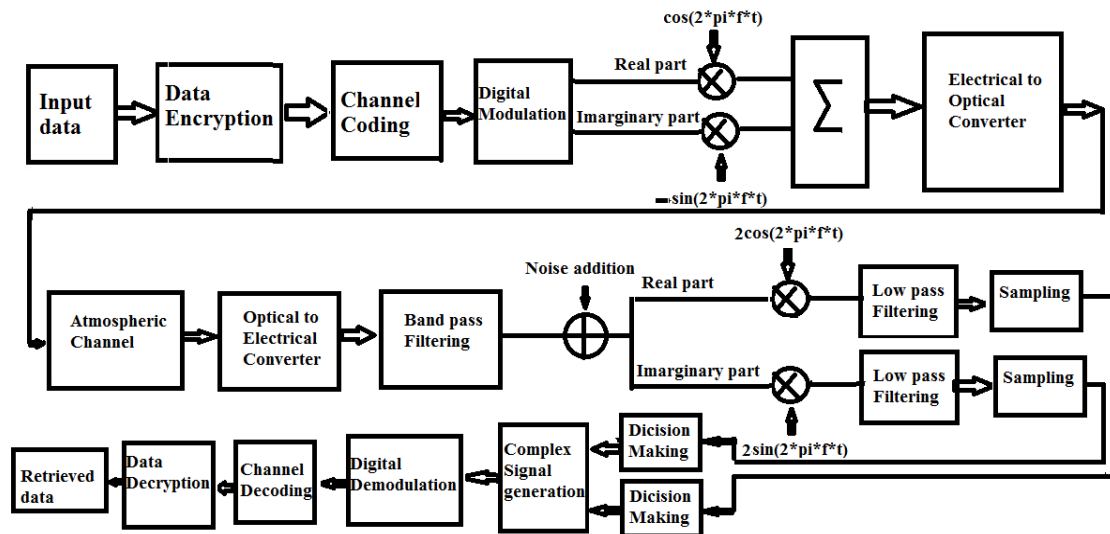


Fig. 1 Block diagram of Subcarrier intensity-modulated Free Space Optical Communication system

The signal is filtered assigning a selective frequency band and subsequently contaminated with additive white Gaussian noise. Its real and imaginary parts are multiplied by carriers with amplitude double as compared to carriers used in the transmitting section, low pass filtered and sampled to make decision for complex signal generation [4]. The generated complex symbols are digitally demodulated, channel decoded and decrypted to recover transmitted signal.

IV. Results and Discussion

We have conducted computer simulations to evaluate the BER performance of a Subcarrier intensity-modulated Free Space Optical Communication system based on the parameters given in Table 1.

Table 1: Summary of the simulated model parameters

No. of bits used	4096
Bit rate	200 Mbps
Subcarrier frequency	1 GHz
Sampling frequency	50 GHz
Data Encryption technique	Symmetric Stream Cipher
Channel Coding	LDPC , Turbo, CRC , BCH and Reed-
Photo detector responsivity	1
Optical Modulation index	1
Modulation	DPSK, QPSK and QAM
Channel	AWGN and Atmospheric Turbulent
Signal to noise ratio, SNR	-10 to 5 dB

It is noticeable that the BER curves depicted in Figure 2 through Figure 6 are clearly indicative of showing distinct system performance under various channel coding and digital modulation schemes. In all cases, the simulated system shows satisfactory performance in QAM and ratifies worst performance in DQPSK digital modulation. In Figure 2, is it observable that the BER values approach zero in QAM and QPSK under scenario of LDPC channel coding and 1dB greater noise power relative to signal power(SNR=-1dB). At -5dB SNR, a

low system performance gain of 0.43 dB is obtained in QAM relative to DQPSK. At higher SNR values greater than 0 dB, the system shows identical performance in all digital modulations. In Figure 3, the BER performance differences for Turbo channel coded FSO system at greater signal power relative to noise power are not well distinguishable from each other in different digital modulations. At highly noisy situation, the system performance degradation is comparatively higher in comparison with LDPC channel coding. In Figure 4, the system performance with CRC channel coding is well defined in different digital modulations. At -10dB SNR value, the BER values are 0.0369, 0.2339 and 0.2959 in case of QAM, QPSK and DQPSK which are indicative of reasonable system performance improvement of 8.02 dB and 9.04 dB in QAM as compared to QPSK and DQPSK. At 3.5 % BER, a SNR gain of .6 dB is achieved in QAM as compared to QPSK. In Figure 5, it is quite obvious that the system performance is quite satisfactory with BCH channel coding. The BER value approaches zero at -8 dB SNR value with QAM digital modulation. Over a significant SNR value region, the BER value approaches zero with all digital modulations. At -10dB SNR value, the BER values are 0.0276, 0.1335 and 0.2295 in case of QAM, QPSK and DQPSK which implies reasonable system performance improvement of 6.85 dB and 9.20 dB in QAM as compared to QPSK and DQPSK. In Figure 6, the Reed-Solomon channel encoded FSO system shows distinct BER performance. At -1dB SNR, BER value approaches zero in all digital modulations. At approximately 5% BER, SNR gain of 3 dB and 4 dB are achieved in QAM as compared to QPSK and DQPSK respectively. At -10dB, system performance enhancement of 3.46 dB and 5.61 dB are achieved in QAM as compared to QPSK and DQPSK (SNR values: 0.062, 0.1375 and 0.2256).

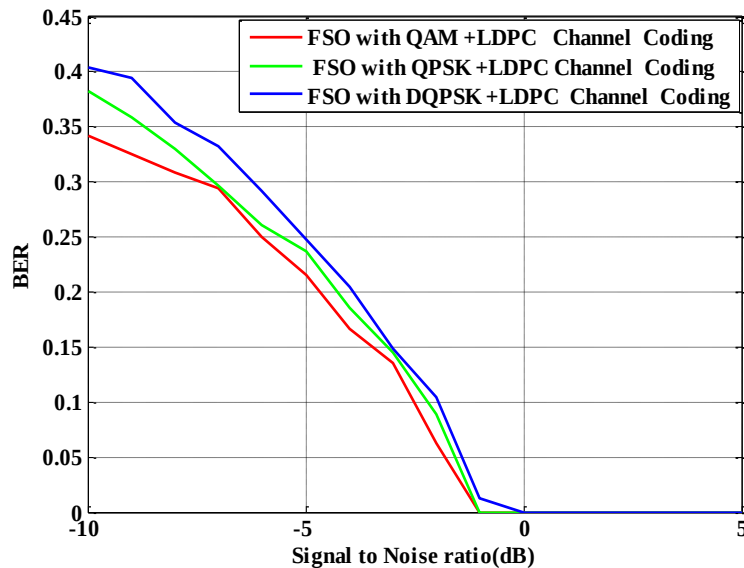


Fig. 2 BER performance comparison of subcarrier intensity-modulated Free Space Optical Communication system under various digital modulations, LDPC channel coding and atmospheric turbulence effect.

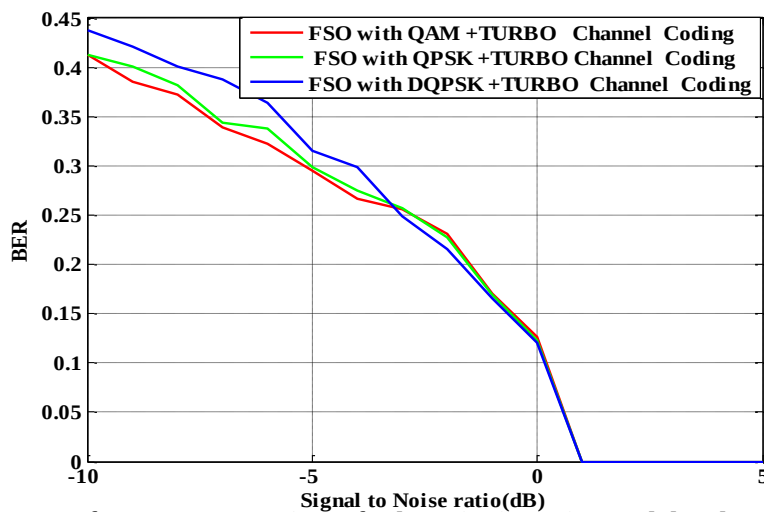


Fig. 3 BER performance comparison of subcarrier intensity-modulated Free Space Optical Communication system under various digital modulations, Turbo channel coding and atmospheric turbulence effect.

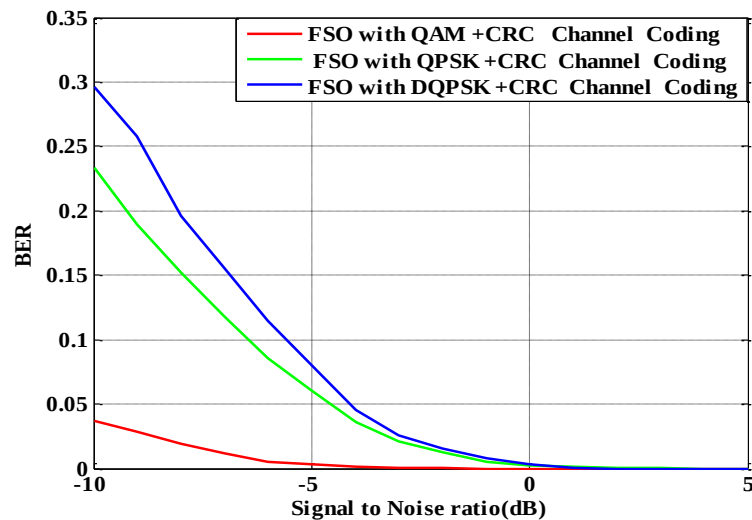


Fig. 4 BER performance comparison of subcarrier intensity-modulated Free Space Optical Communication system under various digital modulations, CRC channel coding and atmospheric turbulence effect.

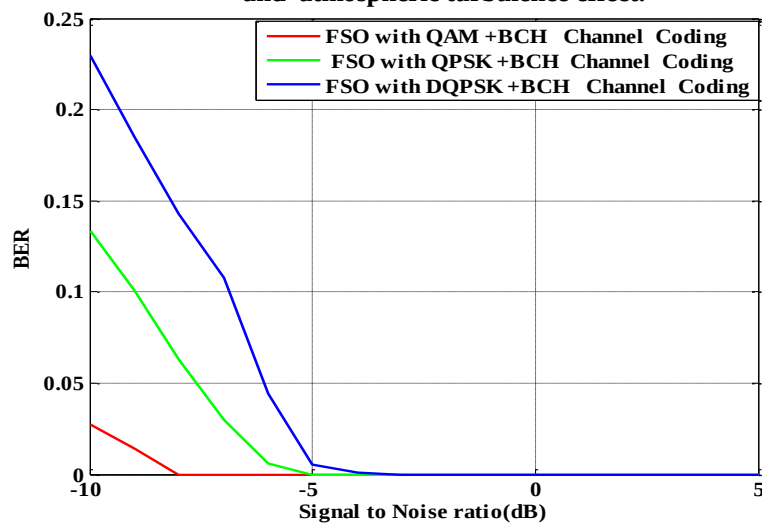


Fig. 5 BER performance comparison of subcarrier intensity-modulated Free Space Optical Communication system under various digital modulations, BCH channel coding and atmospheric turbulence effect.

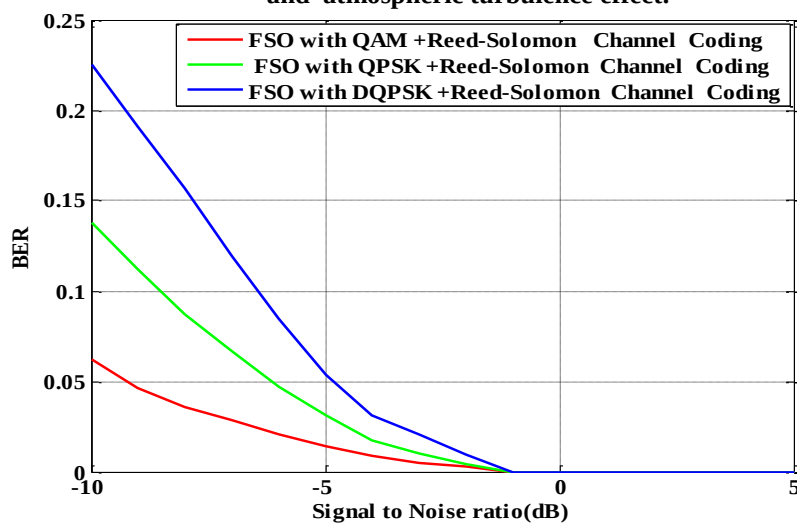


Fig. 6 BER performance comparison of subcarrier intensity-modulated Free Space Optical Communication system under various digital modulations, Reed-Solomon channel coding and atmospheric turbulence effect.

V. Conclusion

With growing demand for bandwidth in mobile communication and significant increasing in number of users, the next-generation wireless communication systems may be linked with implementation of Optical wireless communications (OWC) technology that entails the transmission of information-laden optical radiation through the free-space channel. In this paper we have tried to show that a simplified FSO wireless communication system is capable of showing its robustness in retrieving data in atmospheric turbulent effect. From the simulation based study, it can be concluded that a Subcarrier intensity-modulated Free Space Optical (FSO) Communication system is very much effective to produce its satisfactory system performance under low order QAM digital modulation and BCH channel coding scheme.

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