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Performance Analysis of Multi-group Space Time Encoded OFDM-TDMA Wireless Communication System

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Abstract: *In this paper, we made simulative study on secure data transmission in a multi-group space time encoded OFDM-TDMA wireless communication system. The system under investigation implements a modern hybrid concatenated channel encoder, four signal detectors such as ZF,MMSE, Lattice Reduction-Aided MMSE and BLUE based signal detection under QAM, QPSK and DQPSK digital modulations. Based on the simulation result with MATLAB, it is inferential that the simulated system is highly robust in retrieving transmitted data under Rayleigh fading channel in QAM digital modulation and Lattice-Reduction-aided MMSE signal detection scheme.*
Keywords: *Hybrid concatenated channel encoding, Lattice-Reduction-aided MMSE, ZF, MMSE, BLUE based signal detection MGSTC, SNR*

I. Introduction

Orthogonal Frequency-Division Multiplexing (OFDM) has emerged as a successful air-interface technique. OFDM techniques are also known as Discrete Multi-Tone (DMT) transmissions and are employed in the American National Standards Institute's (ANSI's) Asymmetric Digital Subscriber Line (ADSL), High-bit-rate Digital Subscriber Line (HDSL) and Very-high-speed Digital Subscriber Line (VDSL) standards as well as in the European Telecommunication Standard Institute's (ETSI's) VDSL applications. In wireless scenarios, OFDM has been advocated by many European standards such as Digital Audio Broadcasting (DAB) , Digital Video Broadcasting for Terrestrial television (DVB-T),Digital Video Broadcasting for Handheld terminals (DVB-H), Wireless Local Area Networks (WLANs) and Broadband Radio Access Networks (BRANs) .MIMO-OFDM is the key technology for various cellular communications such as 3GPP-LTE, Mobile WiMAX and IMT-Advanced. The quality of a wireless link viz. Transmission rate, transmission range and transmission reliability can be improved using MIMO-aided OFDM technology [1,2]. Multiple Input Multiple Output (MIMO) communications are generally referred to a collection of signal processing techniques that have been developed to enhance the performance of the wireless communication systems. MIMO techniques incorporates both spatial diversity and spatial multiplexing schemes and improve communications performance by either combating or exploiting multipath scattering in the communications channel between a transmitter and receiver. The use of MIMO techniques has been adopted in various Commercial wireless standards such as IEEE 802.11n (WiFi), IEEE 802.16e (WiMAX), HSPA+ (Enhanced HSPA), LTE (3.9G), LTE-Advanced (4G) and 802.11ac (Enhanced 802.11n) with antenna configurations are of (4 × 4), (4 × 4), (2 × 2), (4 × 4), (8 × 8) and (8 × 8) respectively. In our present study, we have used MIMO technique using multi-group space-time coding (MGSTC) scheme [3].

II. Signal Processing

A. Hybrid Concatenated Channel Encoding

In the history of coding theory, it has been known that many attempts have been made by renowned theorists to develop codes capable of approaching the Shannon limit with an underlying well-defined mathematical structure to simplify decoding and with a random like codeword distribution to enhance the code strength. Hybrid Concatenated Channel coding is one of the modern concatenated coding schemes.

In such coding scheme (Figure 1), a hybrid concatenation of three convolutional codes with linking two interleavers is made exploiting the advantage of both serially and parallelly concatenated coding gains [4].

B. Multi-group space-time coding (MGSTC)

Spatial multiplexing is generally referred to transmitting multiple independent data streams over multipath channels.

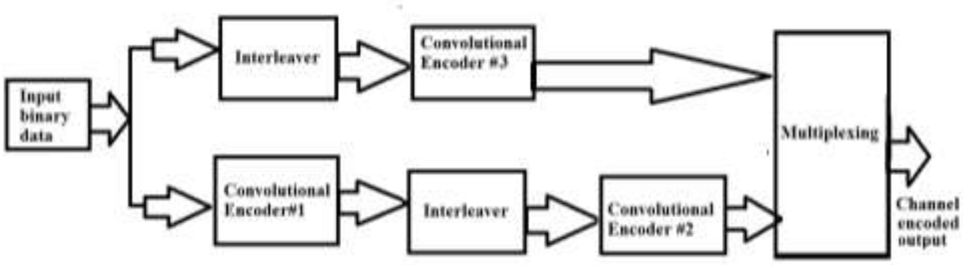

Figure 1: Hybrid Concatenated Channel Encoding

The multi-group space-time coding (MGSTC) scheme achieves both spatial multiplexing and spatial diversity simultaneously. In such scheme, the digitally modulated symbols are rearranged into four groups with each group consisting of eight symbols at a time. The total number of information bits processed in each group under each of the four space time encoder are sixteen as the low order digital modulations(QAM,QPSK and DQPSK) have been used.

C. Lattice Reduction-Aided MMSE Signal Detection

In linear signal detection, the signal model in terms of 4× 4 MIMO channel matrix H, spatially-multiplexed transmitted signal x and received signal y and noise z can be written as:

$$Y=Hx+z \quad (1)$$

In linear signal detection, there is a probability of system performance degradation with increasing noise component the course of linear filtering. Such noise enhancement problem becomes critical especially when the condition number of channel matrix increases. The lattice reduction method is useful for reducing condition number of channel matrix. The Lattice Reduction-Aided MMSE Signal Detection technique uses Lenstrat-Lenstra-Lovasz(LLL) algorithm.

On QR decomposition of channel matrix , Equation (1) can be written as:

$$Y=QRx+z$$
$$=Q_{LLL}R_{LLL}T^{-1}_{LLL}\,x+z \quad (2)$$

where, Q_{LLL} is the orthogonal matrix and T^{-1}_{LLL} is used to recover Q and R from their modifications. Multiplying both sides with Q^{H}_{LLL}, we get

$$Q^{H}_{LLL}y = R_{LLL}T^{-1}_{LLL}\,x + Q^{H}_{LLL}z \quad (3)$$

if, it is considered that $\tilde{\tilde{y}} = Q^{H}_{LLL}y, \tilde{\tilde{x}} = T_{LLL}{}^{-1}x$ and $\tilde{\tilde{z}} = Q_{LLL}{}^{H}z$, Equation (3) is represented in a new form of system equations:

$$\tilde{\tilde{y}} = R_{LLL}\,\tilde{\tilde{x}} + \tilde{\tilde{z}} \quad (4)$$

which is expected to be well conditioned.

The MMSE signal detection technique is applied to the well condition system Equation (4) to yield the estimate of transmitted signal $\tilde{\tilde{x}}$ denoted by $\hat{\hat{x}}$, that is[3,5].

$$\hat{\hat{x}}_{MMSE} = (R^{H}{}_{LLL}\,R_{LLL} + \sigma_n{}^{2}\,I)^{-1}R^{H}{}_{LLL}\tilde{\tilde{y}} \quad (5)$$

where, $\sigma_n{}^{2}$ is the noise variance and I is the identity matrix

D. Linear Signal detection

The multi-group space-time encoded complex signals are processed with multicarrier modulation prior to transmission from each of the four transmitting antennas. In receiving section, two signal detection schemes such as Minimum mean square error (MMSE) and Zero-Forcing (ZF) are used. The MMSE weight matrix can be written in terms of noise variance and channel can be written as:

$$W_{MMSE} = (H^{H}H + \sigma_n{}^{2}I)^{-1}H^{H} \quad (6)$$

and the detected signal from the transmitting antenna in terms of received signal Y and weight matrix is given by

$$\tilde{X}_{MMSE} = W_{MMSE}\,Y \quad (7)$$

In ZF scheme, the ZF weight matrix is given by

$$\mathbf{W_{ZF}} = (\mathbf{H^{H}H})^{-1}\mathbf{H^{H}} \quad (8)$$

and the detected signal from the transmitting antenna is given by[2,3]

$$\tilde{X}_{ZF} = W_{ZF} Y \quad (9)$$

E. Best Linear Unbiased Estimation(BLUE) based Signal detection

In BLUE based signal detection scheme, it is assumed that the channel matrix H is deterministic and the covariance matrix R_{ee} (=E{zz^T}) of the contaminated noise is positive definite and its inversion matrix R^{-1}_{ee} is known or can be estimated. The noise covariance matrix R_{ee} is of dimension 4 × 4. The estimated transmitted signal X_{BLUE} using such scheme can be written as[5]:

$$X_{BLUE} = (H^T R^{-1}_{ee} H)^{-1} H^T R^{-1}_{ee} Y \quad (10)$$

III. System model

The block diagram of the simulated multi-group space time encoded OFDM-TDMA system is shown in Figure 2. It is assumed that a single user is transmitting his/her data utilizing all allocated subcarriers during the time of several OFDM symbols and the OFDM symbols assigned are adaptively changed in each frame. However, the synthetically generated binary data are encrypted using symmetric stream cipher [6] .

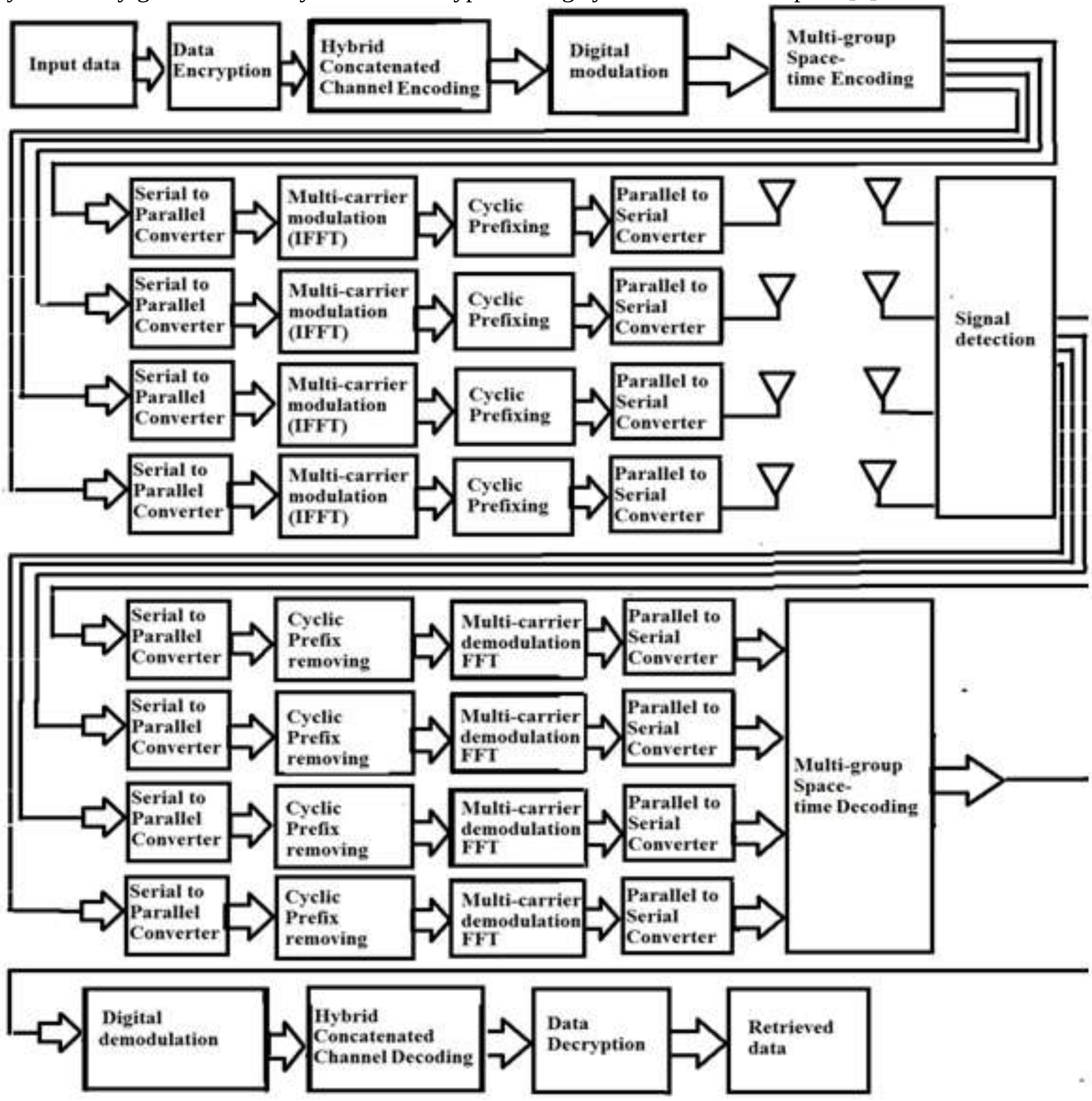

Figure 2: Block diagram of multi-group space time encoded OFDM-TDMA wireless communication system

The encrypted data are channel encoded using hybrid concatenated channel coding scheme. The encrypted and channel encoded data are digitally modulated using QAM, DQPSK and QPSK. The digitally modulated symbols are fed into Spatial demultiplexing section using multi-group space-time coding for production of four data series to be transmitted from antenna after executing various processing steps(Serial to parallel conversion, OFDM modulation, Cyclic prefixing and parallel to serial conversion).In receiving section, all the transmitted signals are detected with linear signal detection schemes and the detected signals are subsequently sent up to the serial–to–parallel (S/P) converter and after that they are processed with cyclic prefix removing scheme, then fed into OFDM demodulator which performs FFT operation on each OFDM block. The FFT operated OFDM block are undergone from parallel–to–serial conversion and fed into Multi-group space-time decoding section. The multiplexed complex symbols are digitally demodulated, channel decoded and decrypted to recover the transmitted data [2,7].

IV. Results and Discussion

In this section, we have presented a series of simulation results to illustrate the significant impact of system performance in terms of BER in a multi-group space time encoded OFDM-TDMA system with simulation parameters tabulated in Table 1.

Table 1: Summary of the Simulated Model Parameters

Data type	**Synthetically generated binary bits**
No of binary bits	8192
Antenna configuration	4-by-4
Spatial multiplexing	Multi-group space time(MGST)
Channel Coding	Hybrid Channel Coding
Data Modulation	QPSK, DQPSK and QAM
IFFT/FFT size	2048
CP length	205
Signal detection Scheme	Lattice Reduction-Aided MMSE, BLUE, MMSE and ZF
Channel	AWGN and Rayleigh fading
Signal to noise ratio, SNR	0 to 5 dB

The simulation results presented in Figure 2 through Figure 6 are clearly indicative of well defined performance with low order Phase shift keying and Quadrature Amplitude modulation signaling and various signal detection schemes. In all cases, we see that the simulated system outperforms with QAM signaling and shows worst performance in DQPSK signaling. In Figure 3 with MMSE signal detection scheme implementation, it is noticeable that with a specific event of both signal and noise power coincidence at 0 dB viz, at identical signal and noise power, the system performance is enhanced by 4.52 dB in QAM as compared to DQPSK(BER values: 0.1621 and 0.4588). At 10% BER, the MGST encoded simulated system with QAM signaling is superior by 4.25 dB in perspective of DQPSK signaling. In Figure 4 with ZF signal detection, the estimated BERs are 0.0787 and 0.4299 in case of QAM and DQPSK at a typically assumed SNR value of 1 dB which justifies a system performance improvement of 7.37 dB. In Figure 5, it is seen that the system performance with implementation of Lattice-Reduction-aided MMSE signal detection scheme has been improved significantly. At 0 dB SNR, the estimated BERs are 0.1309 and 0.4595 in case of QAM and DQPSK which implies a system performance improvement of 5.45 dB. In Figure 6, it is quite observable that at 10% BER, the MGST encoded simulated system with QAM signaling is superior by 1.8 dB and 4.35 dB respectively as compared to QPSK and DQPSK signaling. At 1 dB SNR, a system performance improvement of 7.19 dB is achieved in QAM in perspective of DQPSK signaling (BERs: 0.0773 and 0.4049).

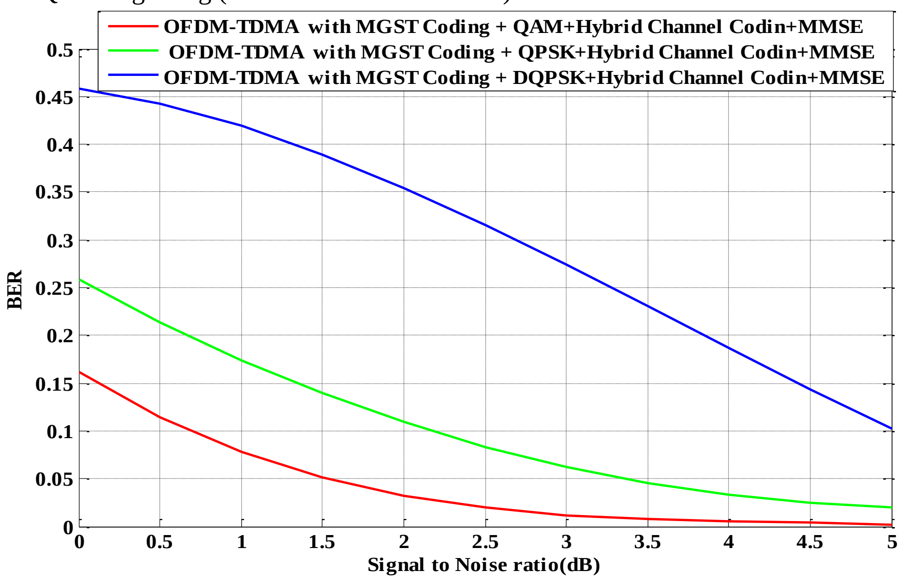

Figure 3: BER Performance of multi-group space time encoded OFDM-TDMA system with implementation of Hybrid Concatenated Channel Encoding, various digital modulation and MMSE signal detection schemes

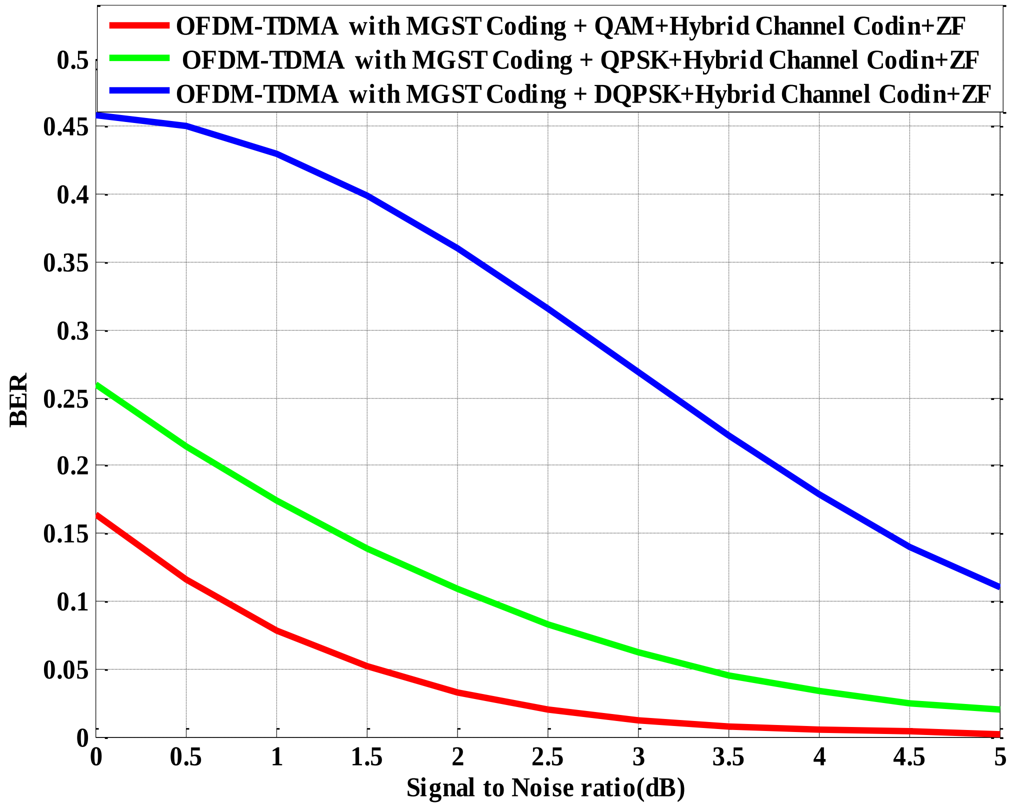

Figure 4: BER Performance of multi-group space time encoded OFDM-TDMA system with implementation of Hybrid Concatenated Channel Encoding, various digital modulation and ZF signal detection schemes

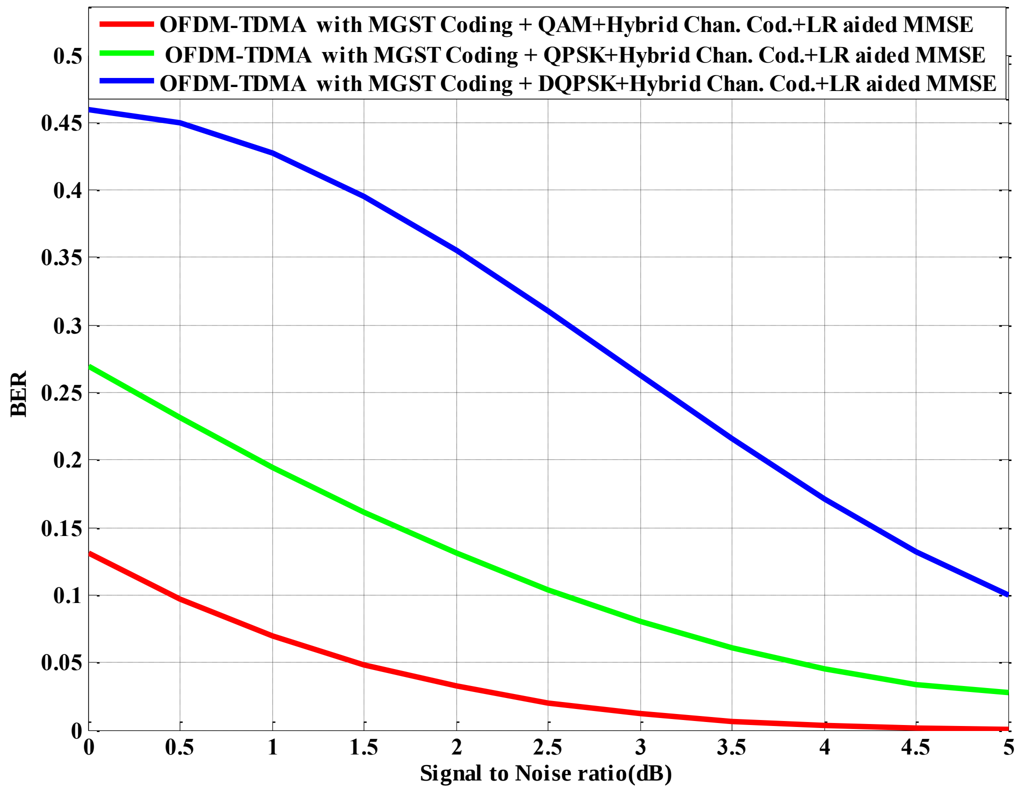

Figure 5: BER Performance of multi-group space time encoded OFDM-TDMA system with implementation of Hybrid Concatenated Channel Encoding, various digital modulation and Lattice-Reduction-aided MMSE signal detection schemes

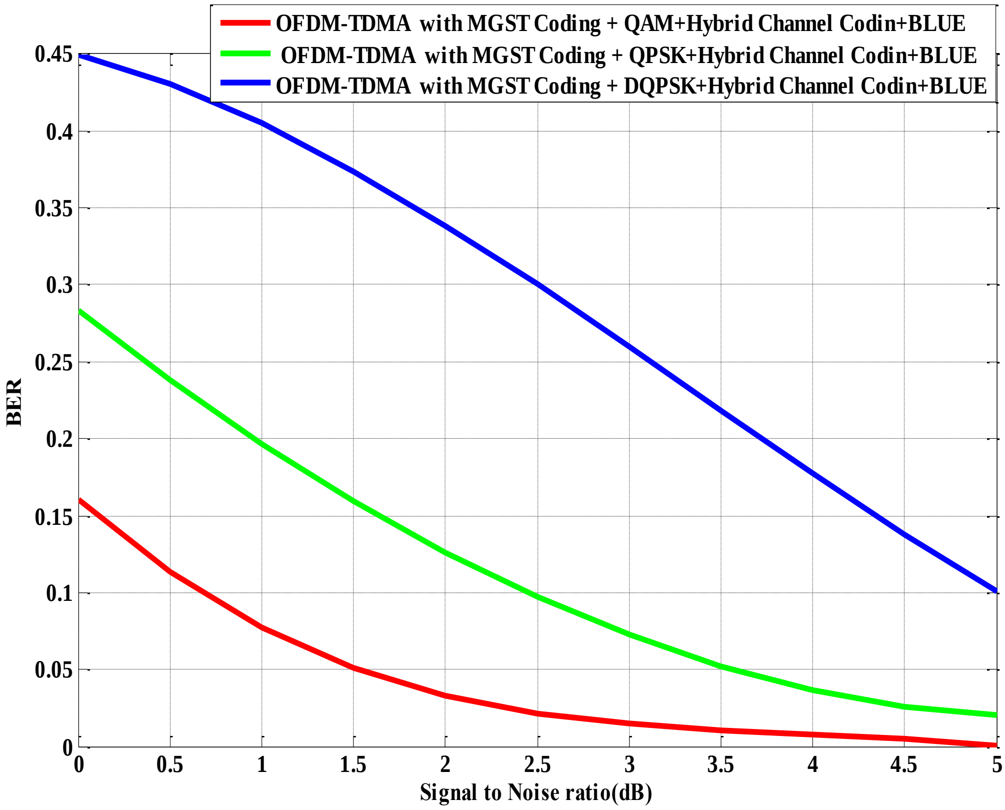

Figure 6: BER Performance of multi-group space time encoded OFDM-TDMA system with implementation of Hybrid Concatenated Channel Encoding, various digital modulation and BLUE based signal detection schemes

V. Conclusions

We have presented simulation results ratifying that the multi-group space time encoded OFDM-TDMA wireless communicatin system can be effectively used for data transmission. It has also been found an interesting result from this study that the system shows degraded performance under implementation of low order DQPSK digital modulation. We have explored that such multi-group space time encoded OFDM-TDMA wireless communication system shows reliable and robust performance using Hybrid concatenated channel encoder and Lattice-Reduction-aided MMSE receiver. In perspective of low order digital modulation, QAM is preferable as compared to QPSK and DQPSK digital modulations.

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