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MIMO-OFDM Using Error Correcting Codes

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Abstract:
In the recent years ,the demand for multimedia communication is growing rapidly. Orthogonal frequency division Multiplexing(OFDM) is used in 4G wireless communication systems because of its more coverage area, high data rate . If a multiple input multiple output (MIMO) Technique is incorporated in OFDM ,it gives high speed and reliable transmission in wireless communication. MIMO is the suitable technique for high speed data multi carrier transmission ,it gives significant improvement in capacity and is used in the long term evaluation standard. If Forward error correction (FEC)codes are incorporated in MIMO-OFDM system, further improvement in performance can be achieved. In this paper an extensive literature survey is carried out for FEC coded MIMO-OFDM systems.
The FEC codes like convolutional codes , Low density parity check(LDPC)codes ,Turbo codes, Polar codes and their Concatenations are applied to MIMO-OFDM system and bit error rate (BER) performances are analyzed .The performance of different FEC-coded MIMO-OFDM systems Is analyzed with different channels (Additive white Gaussian noise(AWGN), Rayleigh, Rician) under different Modulation schemes (PSK16,QAM32).The performace of FEC coded MIMO-OFDM systems is compared with different antenna configurations(2×2,4×4). After comparing the BERperformaces with the above parameters ,the best performance FEC coded MIMO-OFDM systems are determined .

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I. INTRODUCTION

In wireless communication systems high data rate can be achieved with more bandwidth .Increment of band width is difficult due to limitations in the spectrum usage and impractical in most of the cases. OFDM signal consists of more number of sub carriers with good orthogonality and can handle the multipath interference at the receiver [42].MIMO channel has Spacial diversity at both sides of the link , and reduces the multi path fading .MIMO gives gain in capacity ,better reliability and improvement of robustness[17].Typically the number of transmitting antennas to be equal to the number of receiving antennas[44] . To reduce complexity ,in general the number of transmitting antennas is more than that of receiving antennas which is called an over loaded MIMO system[43]. In the decoding process of turbo codes a significant performance degradation occurs in over loaded MIMO system , which reduces the quality of decoder's output[5].For better performance of decoding ,information exchange between decoding blocks and detection blocks can be implemented[5].FEC methods are to be applied to get more efficient MIMO-OFDM system with high data rate , highly reliable wireless communication with minimum BER[41].
Orthogonal space time block codes (OSTBC) are used for attaining diversity at transmitting Antennas[44] , but its coding gain is poor .MIMO-OFDM is added with OSTBC for obtaining sufficient coding gain and getting diversity in both space and time .The performance with respect to bit error rate(BER)can be estimated for OSTBC - MIMO-OFDM. Convolutional code is combined with Alamouti STBC under diverse fading states.FEC codes like Convolutional , turbo codes are used for transmission of video information[25].LDPCcode is combined with

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Alamouti MIMO-OFDM for attaining multi path diversity[44].In the following session a Survey on " MIMO-OFDM with error correcting codes" is carried out[25].

II. LITERATURE SURVEY

Arun Agarwal,SaurabhN.Mehta [2017] presented the BER performance of MIMO-OFDM system with different modulation techniques(BPSK,QPSK,QAM-16,QAM-64), using different antenna configurations (2×2,2×4,4×4) and different error correcting codes [1] .The error correcting codes like Reed Solomon code(RSC),Convolutional code(CC), Low density parity check code(LDPC),Turbo code(TC) are applied to MIMO-OFDM system.The performance was investigated under three models of channel (AWGN,Rayleigh, Rician) [2] .The concatenation of different error correcting codes (RSC+CC,LDPC+CC,TC+CC) were also Applied and simulation result are compared . They investigated that the concatenation of Turbo code with Convolutional code(TC+CC) , QAM-64 modulation, 4×4 antenna configuration for AWGN channel give better performance with minimum BER[3].It is also observed that BER performance of AWGN channel is better than Rician channel and Rician channel performance is better than Rayleigh channel[1],[4].

IlmiawanShubhi, Yukitoshisanada [2017] proposed the Joint decoding for Turbo codes and is called Joint Turbo decoding(JTD) [5].To achieve better throughput, Long term evaluation(LTE) applies MIMO-OFDM withTurbo-Codes.in MIMO-OFDM when the number of transmitting antennas is more than the number of receiving antennas performance become poor [8][44].In Joint turbo decoding Combination of bit streams would be taken from all streams instead of each bit stream separately [6].In joint Turbo decoding Trellis diagrams from all streams are combined using super Trellis diagram .Simulation results are evaluated for 4×2 antenna configuration[7]. Using JTD better throughput can be obtained for MIMO-OFDM with increment of 23% than conventional Turbo decoding .Throughput hike would be 57% ,when compared to single transmit antenna .For highly correlated channel, Throughput increment of 30% can be achieved than conventional turbo decoding and 70% throughput increment can be achieved than single transmit antenna. From simulation results it is also observed that JTD offers low BER than Conventional Turbo decoding[5].

Ali J.Al-Askery , CharalamposC.Tsimenidi [2017] presented the pair wise error probability (PEP) and bit error rate(BER) for MIMO-OFDM using different modulation schemes[9]. PEP is used to obtain upper bound for MIMO-OFDM with convolutional coding or Turbo coding[10]. The performance of MIMO-OFDM can be improved by calculating the Log-likelyhood ratio [LLR]with the help of Probability density function [PDF]rather than gaussionassuption[11].But thePDF increases the over all receiver complexity.It is suggested to apply Newton polynomial interpolation for LLR equation [12].The complexity of this LLR equation is simple and performance is close to exact LLR.It is observed from simulation results that the number of antennas used at the receiver can be reduced by 70 at an signal to noise ratio(SNR) of -14.6dB for 10 users[9].

Kyeong Jin Kim, Tony Reid , and Ronald A. IItis[2008] compared Soft-QRD-M and SPA algorithms on MIMO-OFDM with 16-QAM modulation and 3×3 antenna configuration. It was investigated that there is lot of reduction in the computational complexity of Soft-QRD-M when compared to SPA algorithm[13]. Receivers with iterative operation are designed and they combines the Soft-QRD-M with Turbo and convolutional encoders/decoders[14] .The Computational cost for Soft-QRD-M is drastically reduced for high signal constallations[16] .The BER performance of Soft-QRD-M is estimated for the following combinations with different iterations.1.Turbo-OFDM System with QPSK modulation, 2.Turbo-MIMO-OFDM system with 16-QAM sub-carrier modulation, 3.Turbo-MIMO-OFDM system with QPSK sub-carrier modulation[15].It is discussed from

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simulation results that more the number of iterations better the performance i.e less BER[13].

Lucian Andrei Perisoara , MihaiNeghina , RodicaStoian [2008] presented the BER performance of MIMO-OFDM with different modulation techniques (4-QAM, 16-QAM,64-QAM,256-QAM) [17] .From simulation results it was investigated that the BER is minimum for 256-QAM.BER for Convolutional coded MIMO-OFDM system was evaluated for 4-QAM and 16-QAM with soft decoding/hard decoding with hamming distance[18] .It was observed that 16-QAM out performs with minimum BER when compared to other cases[19].Simulation results are obtained for MIMO-OFDM with concatenated codes[20]. Concatenation of Golay code as inner code and convolutional code as outer code were used. Simulation results are drawn for uncoded, Convolutional code with hard decoding, Convolutional code with soft decoding and concatenated codes. The performance (BER) of concatenated codes outperformed other codes considered here[17].

Xiaoyingshao and CornelisH. Slump[2013] discussed MIMO-OFDM ,which used opportunistic error correction to reduce the power consumption in Analog to digital converters. Opportunistic error was obtained through Fountain codes[21]. The effect of noise and interference is estimated over the TGn Channel .Three FEC layers in different MIMO-OFDM Systems are compared with coding rate R=0.5,QAM-16 Modulation.1.FEC-1:IEEE 802.11n standard which generates interleaved Rate compatible punctured convolutional codes(RCPC),2.FEC-II:IEEE802[22].11n standard gives LDPC code,3.FEC-III:opportunistic error correction obtained from fountain codes. From simulation results it is investigated that FEC-III out performs FECI and FECII.

When comparing FEC-I and FEC-III,the gain of SNR is 8.5dB for FEC-III in the 2×2 system,4.5dB in 4×4 system,2.5dB in 8×8 system.The Signal to noise ratio decreases with increase in number of antennas(M[23]).When comparing FEC-II and FEC-III ,the SNR gain of FEC-III comes down ,when M is changing from two to four,goes up when M changes from four to eight[21],[24].

ArunAgarwal,SaurabhN.Mehta[2017] presented the BER performance of MIMO-OFDM system with different modulation techniques(QPSK,QAM-16,QAM-64),using different antenna configurations(2×2,2×4,4×4) and different error correcting codes was analyzed[25] .The error correcting codes like Reed Solomon code(RSC),Convolutional code(CC),Low density parity check code(LDPC),Turbo code(TC),Polar code(PC) are used[26].The performance is studied with Rician channel. The concatenation of different error correcting codes (RSC+CC, LDPC+CC, TC+CC, PC+CC) were also used and simulation result are compared. It is found that the concatenation of Polar code with Convolutional code(PC+CC)with QAM-64 modulation and, 4×4 antenna configuration gave better performance with minimum BER[27].The proposed (PC+CC) out performs the other concatenations that are considered here with low BER and and high PSNR[28].It is also observed from simulation results ,that PSNR performance of the proposed method PC+CC is better than CC by 37.97%, better than RSC+CC by 31.73%, better than LDPC+CC by 24.52%, better than TC+CC by 14.12%[25].

Gang iao,ZeeshanBabar,LuMa,SongzuoLiu, Jinqiu Wu[2017] discussed the use of under water acoustic (UWA) communication for MIMO-OFDM[29].The propagation capability is poor for electro magnetic(EM) and optical waves .UWA will increase the performance, spectral diversity and band width efficiency[30] .Channel coding is applied for UWA- MIMO-OFDM to protect data in the noisy channel[31].LDPC is the one of the preferable coding techniques for UWA-MIMO-OFDM. Long range under water communication uses acoustic signaling[32].For low diversity order Bit interleaved coded modulation(BICM)scheme is preferable because of its higher hamming distance .Trellis coded modulation(TCM) is preferable for high

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diversity order due to its high coding gain in AWGN channel.Nelson in 2014 applied Turbocode as channel encoder and decoded using iterative decoding algorithm at receiver.This method reduced the effect of acoustic interference and noise in MIMO-OFDM communication system.UWA-MIMO-OFDM communication is new field and there is lot of scope for future research .There is no perfect algorithm developed for this so far ,all thealgorithms developed have to compromise on efficiency and complexity[29].

KoyaWatanabe,ShoichiHiguchi,kazukiMaruta,Chang-Jun Ahn [2017] presented the performance of polar codes for MIMO-OFDM with different coding rates [33].Frequency selective fading channel is used for MIMO-OFDM .The computational complexity of polar codes is simpler than LDPC codes[34] . Polar codes consume low electric power which is the one of the requirements of 5G communications .Two types of detection schemes Zero forcing(ZF) and maximum likely hood detection (MLD) are used under coding rates R=1/2 and R=1/4 with hard decision(Conventional) and soft decision (Proposed[35]).The BER performance is evaluated with ZF &MLD detections with different conditions like uncoded , polar rate 1/2 ,1/4 with hard decision (Conventional) and soft decision (Proposed) [36].It is investigated that at lower SNR(up to 10 dB) of ZF uncoded performs better.At higher SNR of ZF Polar rate 1/4 soft decision out performs other schemes .It is observed that at lower SNR(up to 5 dB) of MLD uncoded performs better.At higher SNR of ZF Polar rate 1/4 soft decision out performs other schemes.It is also proposed to compare the performance of polar codes with other FEC codes as future research work[33].

RuianLiu, Beibeizeng, TingtingChen, NanLiu,Ninghao Yin[2018] discussed the effect of LDPC code on MIMO-OFDM.MIMO-OFDM is one of the techniques of 4G communications[37]. MIMO-OFDM increases system capacity and reduces the frequency selective fading of wireless channel[38] .If Low density parity check code(LDPC) is applied to MIMO-OFDM , it improves anti-noise ability , reliability of the system and makes decoding simple[39],[40].in this paper 64psk,512psk, 1024psk modulated MIMO-OFDM is tested with and without LDPC. It is investigated that in all cases LDPC-MIMO-OFDM outperforms MIMO-OFDM with respect to BER performance[37].

III. SYSTEMMODEL

OFDM is a technique which uses orthogonality principle, reduces the carrier spacing and increases the spectral efficiency[36].Fig.1 shows the block diagram of OFDM system which is superior over FDM. It is one of the efficient modulation techniques and it is more suitable for Networking[1].

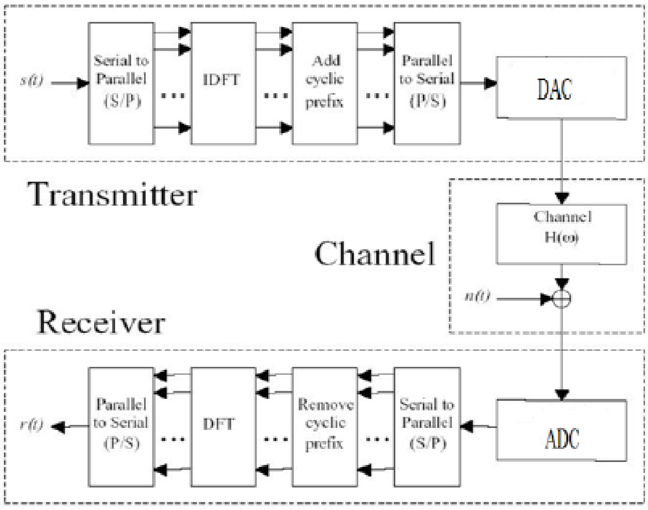

Fig.1 Block diagram of OFDM System.

MIMO technology uses multiple antennas for wireless communication and increase the wireless channel capacity,data transmission rate and spectrum utilization.[40].

Fig.2 shows the block diagram of MIMO-OFDM system.It increases reliability and spectral efficiency Because of its special diversity. FEC-coded MIMO-OFDM is one for which channel coding is incorporated with MIMO-OFDM tocorrect errors that occur in the cnannel. Variety of forward error correcting codes are available.But in Fig.3 LDPC codes are considered.

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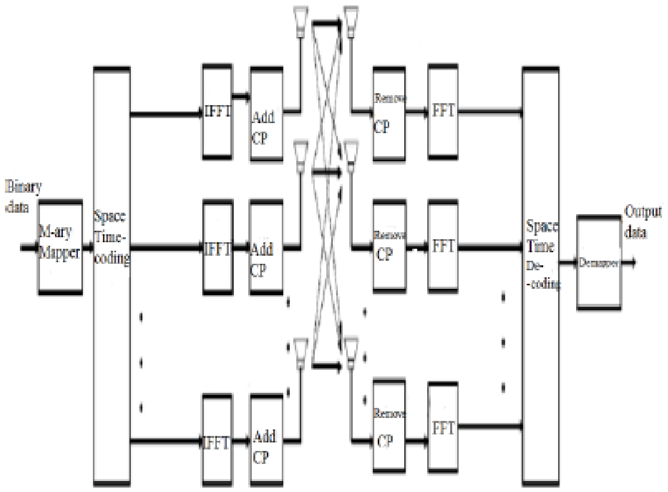

Fig.2 Block diagram of MIMO-OFDM system

The application of low density parity check code [LDPC] can improve anti-interference ability,system reliability and make decoding simple[40].Then LDPC decoder corrects error.Fig3.shows the block diagram of FEC-MIMO-OFDM system. Channel coding is applied here, which add some parity bits .But it is usefull for correcting errors that occur in the channel.

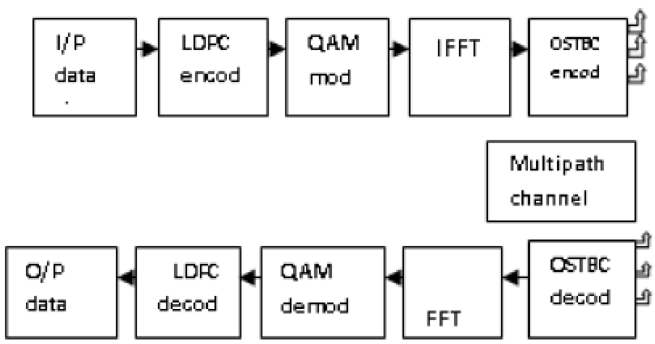

Fig3.Block diagram of LDPC-MIMO-OFDM system

IV. Performance Analysis of FEC Coded - MIMO-OFDM Systems

BER and Peak signal to noise ratio(PSNR) are two metrics used to measure the performance of above systems. BER & PSNR of Concatenated FEC codes for different modulation schemes with different channel environments for data transmission are tabulated below .

BER Analysis:

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	4	3	2	1
QPSK	3	2	0.8	0.4
QAM-16	2	0.8	0.3	0.06
QAM-64	2	0.4	0.1	0.05

Table1. BER for 2×2/10^{-2} For AWGN channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	5	5	4	4
QPSK	5	4	4	4
QAM-16	5	4	3	3
QAM-64	4	4	3	3

Table.2 BER for 2×2/10^{-2} For Rayleigh channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	5	4	4	3
QPSK	4	3	3	2
QAM-16	4	3	2	1
QAM-64	3	2	1	0.8

Table.3 BER for 2×2/10^{-2} For Rician channel

Table.1 to Table.3 shows the BER performance for different forward error correcting codes with different modulation schemes. Turbo code in concatenation with convolutional code gives low bit error rate(better performance) for QAM-64 modulation. It is also noted that the BER performance is better for Additive White Gaussian Noise(AWGN) channel.

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	3	1	0.8	0.4
QPSK	2	0.4	0.1	0.03
QAM-16	0.8	0.1	0.02	0.0006
QAM-64	0.4	0.04	0.005	0.0004

Table.4 BER for 2×4/10^{-2} For AWGN channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	5	4	4	4
QPSK	4	4	3	3
QAM-16	4	3	2	2
QAM-64	4	3	2	1

Table.5 BER for 2×4/10^{-2} For Rayleigh channel

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Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	4	3	3	2
QPSK	3	2	1	0.8
QAM-16	3	1	0.7	0.4
QAM-64	2	0.8	0.3	0.1

Table.6 BER for 2×4/10^{-2} For Rician channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	2	0.8	0.3	0.1
QPSK	0.8	0.1	0.02	0.003
QAM-16	0.3	0.02	0.001	0.0001
QAM-64	0.1	0.003	0.0001	0.000004

Table.7 BER for 4×4/10^{-2} For AWGN channel.

From Table.4 to Table.9 it is observed that Turbo code in concatenation with convolutional code gives(low bit error rate) better performance for QAM-64 with AWGN channel.The antenna configuration required to get low BER is 4×4. The concatenation of coding techniques give better performance than single one.

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	4	4	3	3
QPSK	4	3	2	2
QAM-16	3	2	2	1
QAM-64	3	2	1	0.7

Table.8 BER for 4×4/10^{-2} For Rayleigh channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC
BPSK	4	3	2	1
QPSK	3	1	0.7	0.3
QAM-16	2	0.7	0.2	0.09
QAM-64	1	0.3	0.09	0.02

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-34.3	-31.8	-29.7	-27.0	-24.7
QPSK	-31.8	-27.3	-20.5	-14.2	-7.98
QAM-16	-29.7	-21.2	-10.9	0.410	2.965
QAM-64	-27.4	-13.9	-4.12	6.267	10.44

Table.9 BER for4×4/10-2 For Rician channel

PSNR Analysis:

Table .10 PSNR for 2×2/10^{-2} For AWGN channel

From Table .10 to Table .18, it is observed that all three channels(AWGN,Rayleigh,Rician) give high peak signal to noise ratio(PSNR) for QAM-64. AWGN channel gives best(highest) PSNR performance. The modulation technique to get high PSNR is QAM-64.The antenna configuration(MIMO-OFDM) to get high PSNR is 4×4.The concatenation of coding techniques give better performance than single coding technique.

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-35.5	-34.9	-34.1	-33.3	-32.6
QPSK	-34.9	-33.3	-31.5	-30.3	-28.7
QAM-16	-34.1	-31.8	-29.4	-27.4	-24.6
QAM-64	-33.3	-30.3	-27.4	-24.1	-20.7

Table.11 PSNR for 2×2/10^{-2} For Rayleigh channel.

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-35.3	-34.1	-32.9	-31.9	-30.6
QPSK	-34.2	-31.8	-29.6	-27.1	-24.6
QAM-16	-32.8	-29.6	-26.0	-21.0	-15.0
QAM-64	-31.8	-27.3	-22.5	-12.3	-6.96

Table.12 PSNR for 2×2/10^{-2} For Rician channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-	-26.9	-18.9	-15.2	-7.9

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	31.9				
QPSK	-27.4	-14.4	-3.57	5.380	12.3
QAM-16	-21.7	0.193	9.850	15.29	19.4
QAM-64	-15.0	8.242	15.26	20.23	22.8

Table.13 PSNR for 2×4/10^{-2} For AWGN channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-34.9	-33.4	-32.0	-30.2	-28.7
QPSK	-33.4	-30.3	-27.0	-23.8	-21.1
QAM-16	-31.9	-27.0	-21.9	-13.1	-7.64
QAM-64	-30.3	-24.3	-13.8	-5.14	2.232

Table.14 PSNR for 2×4/10^{-2} For Rayleigh channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-34.1	-32.0	-29.5	-27.2	-24.6
QPSK	-31.8	-27.0	-21.6	-12.7	-8.57
QAM-16	-29.6	-22.6	-7.38	-0.14	3.495
QAM-64	-27.1	-16.1	-0.45	6.440	10.30

Table.15 PSNR for 2×4/10^{-2} For Rician channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-29.4	-22.7	-9.9	-3.6	5.1
QPSK	-	-4.08	10.0	17.0	17.3
	18.9				
QAM-16	-9.3	9.52	16.7	20.7	22.4
QAM-64	-0.09	15.8	20.6	24.9	25.5

Table.16 PSNR for 4×4/10^{-2} For AWGN channel

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-34.2	-31.7	-29.4	-27.1	-25.1
QPSK	-31.9	-27.6	-21.6	-15.2	-4.79
QAM-16	-29.6	-21.0	-9.97	-1.42	2.944
QAM-64	-27.3	-12.8	-1.10	8.320	11.62

Table.17 PSNR for 4×4/10^{-2} For Rayleigh channel.

Modulation scheme	CC	RSC+CC	LDPC+CC	TC+CC	PC+CC
BPSK	-32.9	-29.6	-25.8	-20.6	-12.8
QPSK	-29.6	-22.4	-8.94	-1.69	3.207
QAM-16	-25.8	-10.4	1.103	7.825	11.96
QAM-64	-22.4	-2.17	6.862	14.92	16.11

Table.18 PSNR for4×4/10^{-2} For Rician channel

V. CONCLUSION

In this paper literature survey is conducted on FEC coded- MIMO-OFDM Systems .From the study it is found that the concatenation of Error correcting codes gives better performance .It is proposed to combine polar codes with convolutional codes to get best performance in term of BER and PSNR.The proposed method performs well in terms of computational complexity and electric power

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consumption to meet one of the demand conditions of 5G communication.

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