



Impact of Various Concatenated Channel Coding Scheme on Performance Assessment of a MIMO OFDM System

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Abstract: In this paper, we made a comprehensive BER performance simulative study on synthetically generated data transmission in a MIMO-OFDM wireless communication system. The system under investigation implements various types of modern and classical channel coding schemes in serially concatenated form such as Repeat and Accumulate(RA), Single Parity Check (SPC), Cyclic Redundancy Check (CRC), Bose–Chaudhuri–Hocquenghem (BCH), Low-Density Parity Check (LDPC) and $\frac{1}{2}$ -rated Convolutional under scenario of Rayleigh and Weibull fading channels. Based on the simulation result with MATLAB, it is quite noticeable that the simulated system is highly robust in retrieving transmitted data under Weibull fading channel in QAM digital modulation, ZF channel equalization technique and concatenated channel coding implementing Repeat and Accumulate and Single parity check

Keywords: MIMO-OFDM, Concatenated Channel coding, Bit Error rate (BER), AWGN and Rayleigh and Weibull fading channels.

I. Introduction

Multiple Input and Multiple Output(MIMO) signal processing techniques have been developed to enhance the performance of wireless communication systems using multiple antennas at the transmitter, receiver, or both. MIMO techniques improve communications performance by either combating or exploiting multipath scattering in the communications channel between a transmitter and receiver. MIMO techniques combat multipath fading effects by creating spatial diversity and exploit multipath in order to achieve higher data rate through performance of spatial multiplexing[1].

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 [2, 3].

II. Channel Coding

In this paper, the synthetically generated binary data are processed with serially concatenated channel coding schemes utilizing various codes such as cyclic redundancy check (CRC), Bose–Chaudhuri–Hocquenghem(BCH), low-density parity-check(LDPC), Repeat and Accumulate(RA),

Single parity checks (SPC) and $\frac{1}{2}$ -rated Convolutional. In CRC coding, the binary data stream 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 BCH channel coding, the 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 [4, 5].

In LDPC coding, $\frac{1}{2}$ -rated irregular LDPC code is used with a code length of 1024 bits. Its parity-check matrix [H] is a sparse matrix with a dimension of 512×1024 and contains only three 1's in each column and six 1's in each row. The parity-check matrix [H] is formed from a concatenation of two matrices [A] and [P] ([H] = [A] [P]), each has a dimension of 512×512). The columns of the parity-check matrix [H] are rearranged to produce a new parity-check matrix [newH]. With rearranged matrix elements, the matrix [A]

becomes non-singular and it is further processed to undergo LU decomposition. The parity bits sequence $[p]$ is considered to have been produced from a block based input binary data sequence $[u]=[u_1u_2u_3u_4\ldots u_{512}]^T$ and three matrices $[P]$ (of $[newH]$), $[L]$ and $[U]$ using the following Matlab notation :

$p = \text{mod}(U \setminus (L \setminus z), 2)$; where, $z = \text{mod}(P * u, 2)$;

The LDPC encoded 1024×1 sized block based binary data sequence $[c]$ is formulated from concatenation of parity check bit p and information bit u as: $[c] = [p; u]$

The first 512 bits of the codeword matrix $[c]$ are the parity bits and the last 512 bits are the information bits. In iterative Log Domain Sum-Product LDPC decoding Algorithm, the transmitted bits are retrieved [6, 7].

In RA, a powerful modern error-correcting coding scheme, an information block u (usually binary) of length 2048 is repeated 2 times and permuted by an interleaver of length 4096. The interleaved binary data block z is passed through a truncated rate-1 two-state convolutional encoder whose output x is the Repeat and Accumulate encoded binary data and is given by $x = zG$, where G is an 4096×4096 matrix with 1s on and above its main diagonal and 0s elsewhere. In SPC channel coding, the transmitted binary bits are rearranged into very small codewords consisting of merely two consecutive bits. In such coding, (3, 2) SPC code is used with addition of a single parity bit to the message $u = [u_0, u_1]$, so that the elements of the resulting codeword $x = [x_0, x_1, x_2]$ are given by

$$x_0 = u_0, x_1 = u_1 \text{ and } x_2 = u_0 \boxplus u_1$$

Where $\boxplus$ denotes the sum over GF (2) [8].

III. Multipath Fading Models

Multipath fading is caused by atmospheric ducting, ionosphere refraction, and reflection from various objects, so randomly delayed, reflected, scattered, and diffracted signal components combine in a constructive or destructive manner. Multipath fading causes short-term signal variations, and its influence on the signal envelope has been statistically modeled by various models. A few of such models used in this present study are given below.

In a MIMO system with flat fading wireless channel, the received signal y , 4×4 MIMO channel H and noise n can be modeled as follows:

$$y = Hx + n \quad (1)$$

Each of sixteen h_{ij} components of channel matrix H describes the channel gain between the i^{th} receiving antenna and the j^{th} transmitting antenna.

The complex envelope h_{ij} can be written in terms of zero mean statistically independent Gaussian in-phase $X_{\text{inphase-ij}}$ and quadrature $X_{\text{quad-ij}}$ components, each with a variance of σ^2 . In **Rayleigh fading model**, a Rayleigh distribution random variable r can be written as :

$$r = |X_{\text{inphase-ij}} + jX_{\text{quad-ij}}| = \sqrt{X_{\text{inphase-ij}}^2 + X_{\text{quad-ij}}^2} \quad (2)$$

Its PDF (Probability Density Function) takes the following form:

$$f_R(r) = \frac{2r}{W} \exp\left(-\frac{2r^2}{W}\right) \quad (3)$$

With $W=2\sigma^2$ representing the average value of signal power. In **Weibull fading model**, the complex envelope h_{ij} can be written as:

$$h_{ij} = (X_{\text{inphase-ij}} + jX_{\text{quad-ij}})^{2/\beta_{ij}} \quad (4)$$

Where, $j = \sqrt{-1}$ and β_{ij} is the Weibull fading parameter ($\beta_{ij} > 0$)

The Weibull fading model, Z_{ij} can be expressed as [9, 10]

$$(|X_{\text{inphase-ij}} + jX_{\text{quad-ij}}|)^{2/\beta_{ij}} = (X_{\text{inphase-ij}}^2 + X_{\text{quad-ij}}^2)^{1/\beta_{ij}} \quad (5)$$

IV. Signal Processing

The synthetically generated binary data are channel encoded in serially concatenated coding scheme using outer and inner encoder prior to conversion into complex digitally modulated symbols. The symbols are spatially demultiplexed and fed into each of the four transmitting section. In each section, the signals are modulated in OFDM demodulator and transmitted from each antenna. In OFDM modulator section, serial to parallel, Cyclic prefixing for ISI reduction are executed. In receiving section, Zero forcing channel equalization is used. The retrieved transmitted signal are processed in OFDM demodulator section and subsequently multiplexed, digitally demodulated and channel decoded for retrieving data [3, 11, 12].

V. Results and Discussion

In this section, we present a series of simulation results to illustrate the significant impact of concatenated channel coding scheme on system performance in terms of BER in a ZF aided MIMO-OFDM wireless

communication system. The Simulation study has been made using **MATLAB 2012a** based on the parameters given in Table 1. It is assumed that the channel state information (CSI) is available at the receiver and the fading process is approximately constant during each digitally modulated symbolic period.

Table 1: Summary of the Simulated Model Parameters

No. of synthetically generated binary data used	2048
Channel Coding scheme used in serial concatenation	Repeat and Accumulate (RA), Single parity check (SPC), cyclic redundancy check (CRC), Bose–Chaudhuri–Hocquenghem (BCH), low-density parity check (LDPC) and 1/2-rated Convolutional
Digital modulation	QAM and QPSK
No of subcarriers (FFT Size)	1024
CP length	105 symbols
No of iterations considered in LDPC decoding	10
Antenna Configuration (User Equipment and Base station)	(4,4)
Signal Detection Scheme	Zero-Forcing(ZF)
Channel	AWGN, Rayleigh fading and Weibull fading
Signal to noise ratio (SNR)	0 to 5 dB

Figure 1 through Figure 5 depict the bit-error rate performance of the concatenated channel coding scheme in terms of BER in a ZF aided MIMO-OFDM wireless communication system.

In figure 1, it is noticeable that the serially concatenated channel coding scheme using 1/2-rated convolutional and Low-Density Parity-Check (LDPC) MIMO-OFDM system with QPSK digital modulation in weibull fading channel shows almost flat BER performance at low SNR value area. In such a case, performance improvement can be observed with increase in SNR values. From this Figure, we can see that the system outperforms with QAM digital modulation in weibull fading channel. At 5% bit error rate, the concatenated channel encoded MIMO-OFDM system with QAM in weibull fading channel is superior by 0.75 dB and 1.55 dB respectively as compared with QAM and QPSK in rayleigh fading channel. In figure 2, it is seen that the BER performance of concatenated channel coding schemes using Repeat and Accumulate and LDPC MIMO-OFDM system becomes poorer with QPSK in both weibull and rayleigh fading channel. At a typically assumed SNR value of 3 dB, the estimated BER values are 0.0597 and 0.1625 for QAM in weibull fading channel and QPSK in rayleigh fading channel respectively which implies system performance improvement by 4.35 dB.

In figure 3, it is observable that in case of identical signal and noise power, BER values for QAM under weibull fading channel and QPSK under rayleigh fading channel using Repeat and Accumulate and Bose–Chaudhuri–Hocquenghem (BCH) as concatenated channel coding scheme are 0.099 and 0.1650 respectively which implies system performance improvement by 2.22 dB. In figure 4, it is clearly visible that the Repeat and Accumulate and Cyclic Redundancy Check (CRC) encoded system exhibits better BER performance with deployment of QAM digital modulation in weibull fading channel as compared to other systems under both fading channels. In figure 5, the estimated BERs are 0.035 and 0.0685 in case of QAM and QPSK at SNR value of 3 dB with serially concatenated channel coding scheme using Repeat and Accumulate and Single Parity Check (SPC) under weibull fading channel and under rayleigh fading channel respectively which ratify system performance improvement of 2.92 dB.

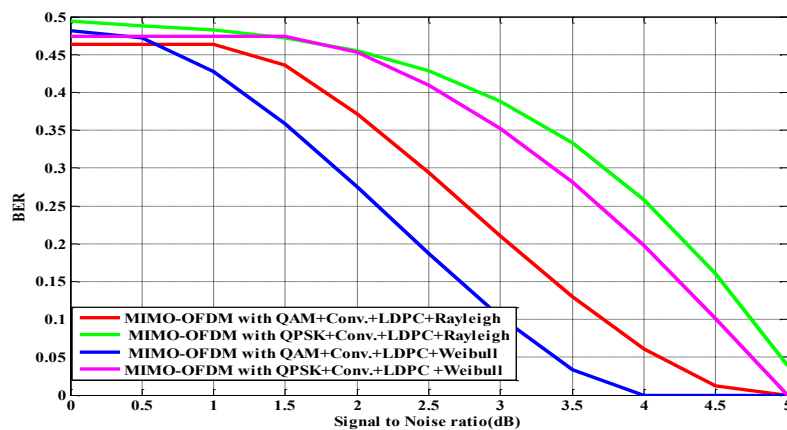


Fig. 1: BER performance comparison of MIMO-OFDM wireless communication system under various digital modulations and concatenated channel coding with Convolutional and LDPC.

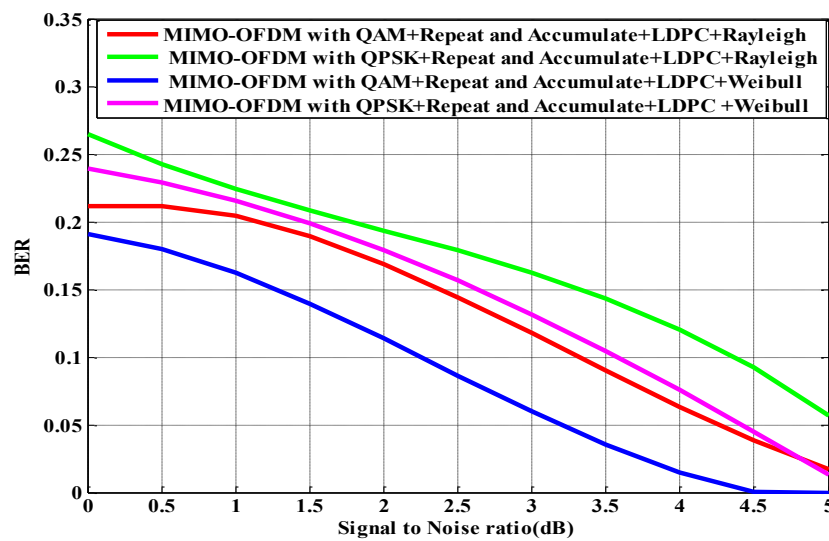


Fig. 2: BER performance comparison of MIMO-OFDM wireless communication system under various digital modulations and concatenated channel coding with Repeat and Accumulate and LDPC.

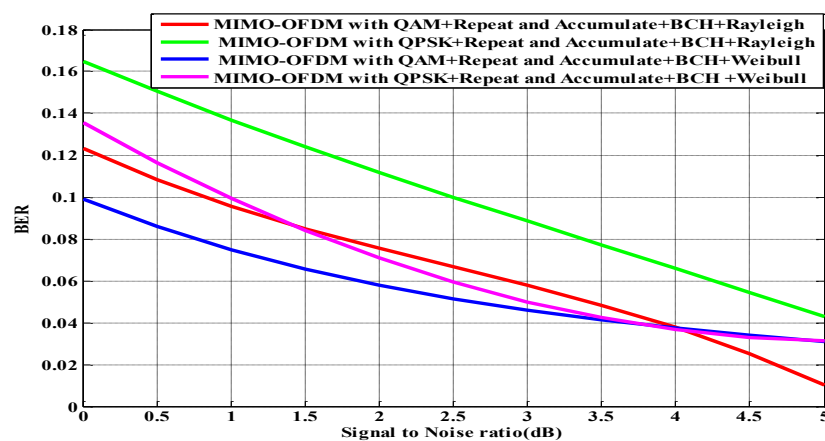


Fig. 3: BER performance comparison of MIMO-OFDM wireless communication system under various digital modulations and concatenated channel coding with Repeat and Accumulate and BCH.

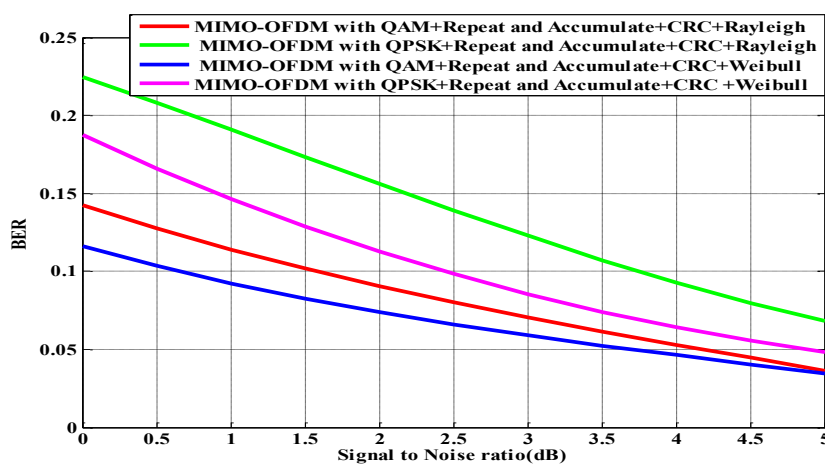


Fig. 4: BER performance comparison of MIMO-OFDM wireless communication system under various digital modulations and concatenated channel coding with Repeat and Accumulate and CRC.

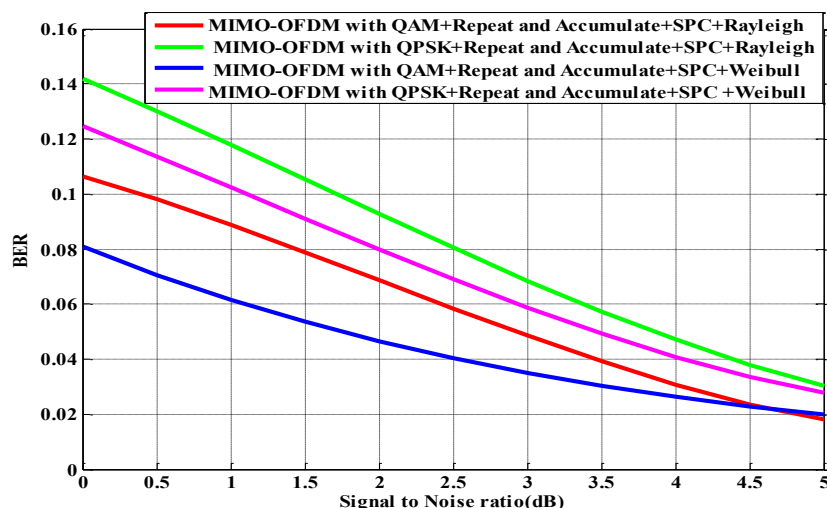


Fig. 5: BER performance comparison of MIMO-OFDM wireless communication system under various digital modulations and concatenated channel coding with Repeat and Accumulate and SPC.

VI. Conclusion

In this paper, we have presented simulation results utilizing various types of modern and classical channel coding schemes in ZF channel equalization aided MIMO-OFDM wireless communication system. The system performance results give a clear indication of selecting modern powerful error-correcting codes used in channel coding schemes. However, it can be concluded that under weibull fading channel, the ZF channel equalization aided MIMO- OFDM wireless communication system is capable of showing improved and robust performance under implementation of low order QAM digital modulation, Repeat and Accumulate and Single parity check based channel coding schemes in concatenated form.

References

- [1] Jerry R. Hampton, 2014: Introduction to MIMO Communications, Cambridge University Press, United Kingdom
- [2] Lajos Hanzo, Yosef (Jos) Akhtman, Li Wang and Ming Jiang, 2011: MIMO-OFDM for LTE, Wi-Fi and WiMAX, John Wiley and Sons Ltd, United Kingdom.
- [3] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, 2010. MIMO-OFDM Wireless Communications with MATLAB, John Wiley and Sons (Asia) Pte Limited, Singapore
- [4] Wicker, Stephen B., Error Control Systems for Digital Communication and Storage, Upper Saddle River, NJ, Prentice Hall, 1995.
- [5] Clark, G. C., and Cain, J. B., Error-Correction Coding for Digital Communications, New York, Plenum Press, 1981.
- [6] Christian B. Schlegel and Lance C. Perez, 2004: Trellis and turbo coding, John Wiley and Sons, Inc., publication, Canada
- [7] Bagawan Sewu Nugroho, <https://sites.google.com/site/bsnugroho/ldpc>
- [8] Giorgio M. Vitetta, Desmond P. Taylor, Giulio Colavolpe, Fabrizio Pancaldi and Philippa A. Martin, 2013: Wireless Communications Algorithmic Techniques, John Wiley and Sons Ltd, United Kingdom
- [9] Stefan R. Panić, Mihajlo Stefanović, Jelena Anastasov and Petar Spalević, 2014: Fading and Interference Mitigation in Wireless Communications, CRC Press, Taylor and Francis Group, Florida, USA
- [10] Mzabalazo Lupupa, Mqhele E. Dlodlo, 2009: Channel Capacity Performance of Transmit Antenna Selective MIMO System in Weibull Fading, Proceedings of SATNAC, Royal Swazi Spa, Ezulwini Valley, Swaziland, <http://www.satnac.org.za/proceedings/2009/papers.htm>
- [11] Goldsmith, Andrea, 2005: Wireless Communications, First Edition, Cambridge University Press, United Kingdom.
- [12] L. J. Cimini, Jr, 1985: Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing, IEEE Transaction on Communication, vol. COM-33, pp. 665-675.