



Impact of Channel Concatenation in 3D MIMO encoded 4x2mm Wave Wireless Communication System on Color Image Transmission

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Abstract: In this paper, we made a comprehensive BER performance simulative study on the color image transmission in a 3D MIMO encoded 4x2 mm Wave wireless communication system. The simulated system under investigation implements various types of modern and classical channel coding schemes such as Repeat and Accumulate(RA), cyclic redundancy check(CRC), (3,2) single paritycode(SPC), Bose–Chaudhuri–Hocquenghem(BCH), low-density parity check (LDPC), AES Block Cipher aided and ½-rated Convolutional both in individual and concatenated form. Based on the simulation result with MATLAB, it is quite noticeable that the simulated system is highly robust in retrieving transmitted color image under mmWave MIMO fading channel in QAM digital modulation and concatenated channel coding scheme with LDPC and ½-rated Convolutional.

Keywords: 3D MIMO, 1 channel concatenation,, Bit Error rate (BER), AWGN and mmWave MIMO channel

I. Introduction

MmWave wireless communication is now a day's being treated as an enabling technology that has myriad applications to existing and emerging wireless networking deployments. With the ever increasing demands in higher data rate, there is a growing interest in exploiting massive amount of unlicensed millimeter-wave spectrum (30-300 GHz), for next generation(5G) Network. Due to explosive demand for high quality video streaming from mobile devices (e.g., tablets, smart-phones), the mobile network operators (MNOs) are facing unprecedented challenge to offer higher data rates that can keep up with this demand for high quality video. It is noticeable that 50% of the traffic in cellular networks today is video. As a first step in a mmWave communications revolution, an emphasis is given on 60GHz WPAN and WLAN deployment. To accommodate continued growth in the Internet and cloud-based applications, Internet service providers and major Web portals are building thousands of data centers each year and these data centers are used by all major Internet companies, including Google, Microsoft, Yahoo, and Amazon, to distribute processing, memory storage, and caching throughout the global Internet. The mmWave wireless communication using 60 GHz can be effectively used in such Data centers. Future users of data -hungry wireless devices are expected to be greatly benefited from the pervasive availability of massive bandwidths at mmWave frequencies. [1-3].

In this present paper, we made a simulation study on the performance of a mmWave wireless communication under utilization of a robust and efficient space-time block coding scheme (3D MIMO) and various channel coding schemes.

II. Signal Processing

In our present simulation based study, a MIMO transmission with 4 transmit and 2 receive antennas over flat mmWave fading channel has been considered. With extracted binary data from decomposed R,G and B components of a typically assumed color image, the data are channel encoded and subsequently interleaved prior to converted into block wise digitally modulated complex symbols consisting of eight consecutive symbols $s_1, s_2, \dots, s_8$. In scenario of noise contaminated color image processing, 2-D Median Filtering technique is used for noise reduction. The 2-D Median Filter is a non-linear filter or order-static filter used for noise reduction. In such scheme, 3x3 neighborhood window is used. This filter simply sorts all pixel values within the window, finds the median value, and replaces the original pixel value with the median value[4]. For the purpose of making FEC (Forward error correction), a brief overview of various channel coding schemes used is given below.

In (3,2) SPC (Single parity code) encoding scheme, the transmitted binary bits are rearranged into very small codeword, $x = [x_0, x_1, x_2]$ consisting of merely two consecutive bits $[x_0, x_1]$ and an additional single parity bit, $x_2 = x_0 \oplus x_1$ where, $\oplus$ denotes the sum over GF(2). In Repeat and Accumulate (RA), a powerful modern error-correcting channel coding scheme, the extracted binary bits from the audio signal is rearranged into blocks with each block containing 2048 binary bits. The binary bits in each block is repeated 2 times and

permuted by an interleaver of length 4096. The interleaved binary data block $\underline{z}$ is passed through a truncated rate-1 two-state convolutional encoder whose output $\underline{x}$ is the Repeat and Accumulate encoded binary data and is given by $\underline{x} = \underline{z}G$, where G is an 4096×4096 matrix with 1s on and above its main diagonal and 0s elsewhere[5]. In Convolutional Channel Coding, Convolutional codes are commonly specified by three parameters (n,k,m) : n = number of output bits; k = number of input bits; m = number of memory registers. The quantity k/n called the code rate and it is a measure of the efficiency of the code. The constraint length $L(=k(m-1))$ represents the number of bits in the encoder memory that affect the generation of the n output bits. The presently considered Convolutional Channel Encoder is specified with $\frac{1}{2}$ coding rate, a constraint length of 7 and code generator polynomials of 171 and 133 in octal numbering system. The code generator polynomials $G1$ and $G2$ can be written as [6].

$$\begin{aligned} G1 &= x^0 + x^2 + x^3 + x^5 + x^6 = 1 \ 0 \ 1 \ 1 \ 0 \ 1 \ 1 = 133 \\ G2 &= x^0 + x^1 + x^2 + x^3 + x^6 = 1 \ 1 \ 1 \ 1 \ 0 \ 0 \ 1 = 171 \end{aligned} \quad (1)$$

In LDPC (Low density parity-check matrix) 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 $[u]=[u_1 u_2 u_3 u_4 \dots u_{512}]^T$ and three matrices $[P]$ (of $[newH]$), $[L]$ and $[U]$ using the following Matlab notation :

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

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[7,8]. In AES Block Cipher aided channel coding, the input binary data are separately convolutionally encoded and encrypted and the two outputs are multiplexed into a single bit stream under such AES Block Cipher based channel coding scheme [9].

In CRC(cyclic redundancy check) 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(Bose–Chaudhuri–Hocquenghem) channel coding, the data are encoded in $[127,64]$ which implies that its each 64-elements based row represents a message word and additional 63 parity bits are appended at the end of each message word [10,11].

III. MIMO system model

We consider a mmWave MIMO fading channel with N_t transmitting and N_r receiving antennas, it is expected that such channel H_{mmw} is assumed to be the sum of all propagation paths that are scattered in N_c clusters with each cluster contributing N_p paths. Under these scenario, the mmWave channel 2×4 sized H_{mmw} can be written with consideration of path loss ρ as:

$$H_{mmw} = \sqrt{\frac{N_t N_r}{N_c N_p \rho}} \sum_{i=1}^{N_c} \sum_{l=1}^{N_p} \alpha_{il} a_{MS}(\theta_{il}) a_{BS}(\phi_{il})^H \quad (2)$$

where, α_{il} is the complex gain of the i -th path in the l -th cluster which follows $C N(0,1)$. For the (i,l) -th path, θ_{il} and ϕ_{il} are the angles of arrival/departure(AoA/AoD), while $a_{MS}(\theta_{il})$ and $a_{BS}(\phi_{il})$ are the receive and transmit array response vectors at the azimuth angles of θ_{il} and ϕ_{il} respectively with elevation dimension ignoring.

The estimated mmWave channel H_{mmw} is normalized to satisfy

$$E\{\|H_{mmw}\|_F^2\} = N_t N_r \quad (3)$$

where, $\|\bullet\|_F$ is the Frobenius norm and the normalized 2×4 sized mmWave channel H matrix is obtained through hadamard product (element wise multiplication) of H_{mmw} with 2×4 sized normalization factor matrix F_{norm} such that

$$\mathbf{H} = F_{norm} \odot H_{mmw} \quad (4)$$

where, the symbol $\odot$ denotes the Hadamard product and each element of F_{norm} is

$$\frac{1}{|F_{norm}(i, j)|} \text{ and } |F_{norm}(i, j)| \text{ denotes the magnitude of the } (i, j)\text{th element of } F_{norm}$$

With available knowledge of the geometry of uniform linear antenna arrays $\mathbf{a}_{BS}(\phi_{il})$ is defined as:

$$\mathbf{a}_{BS}(\phi_{il}) = \frac{1}{\sqrt{N_t}} [1, e^{j\frac{2\pi}{\lambda} d \sin(\phi_{il})}, \dots, e^{j(N_t-1)\frac{2\pi}{\lambda} d \sin(\phi_{il})}]^T \quad (5)$$

and

$$\mathbf{a}_{MS}(\theta_{il}) = \frac{1}{\sqrt{N_r}} [1, e^{j\frac{2\pi}{\lambda} d \sin(\theta_{il})}, \dots, e^{j(N_r-1)\frac{2\pi}{\lambda} d \sin(\theta_{il})}]^T \quad (6)$$

where, λ is the signal wavelength and d is the distance between two consecutive antenna elements [12,13].

The signal model in terms of received signal $\mathbf{Y} \in \mathbb{C}^{2 \times 4}$, mmWave MIMO channel coefficient $\mathbf{H} \in \mathbb{C}^{2 \times 4}$, the transmitted signal $\mathbf{X} \in \mathbb{C}^{4 \times 4}$ and the complex valued AWGN component $\mathbf{N} \in \mathbb{C}^{2 \times 4}$ can be written in matrix form as:

$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{N} \quad (7)$$

In Equation (7), $\mathbf{X}$ is the 3D MIMO encoded signal ($\mathbf{X}_{3D}$) transmitted in four time slots and can be written as:

$$\mathbf{X}_{3D} = \begin{bmatrix} X_{Golden,1} & -X_{Golden,2}^* \\ X_{Golden,2} & X_{Golden,1}^* \end{bmatrix} = \frac{1}{\sqrt{5}} \begin{bmatrix} \alpha(s_1 + \theta s_2) & \alpha(s_3 + \theta s_4) & -\alpha^*(s_5 + \theta s_6) & -\alpha^*(s_7 + \theta s_8) \\ i\bar{\alpha}(s_3 + \bar{\theta} s_4) & \bar{\alpha}(s_1 + \bar{\theta} s_2) & -i\bar{\alpha}^*(s_7 + \bar{\theta} s_8) & -\bar{\alpha}^*(s_5 + \bar{\theta} s_6) \\ \alpha(s_5 + \theta s_6) & \alpha(s_7 + \theta s_8) & \alpha^*(s_1 + \theta s_2) & \alpha^*(s_3 + \theta s_4) \\ i\bar{\alpha}(s_7 + \bar{\theta} s_8) & \bar{\alpha}(s_5 + \bar{\theta} s_6) & -i\bar{\alpha}^*(s_3 + \bar{\theta} s_4) & -\bar{\alpha}^*(s_1 + \bar{\theta} s_2) \end{bmatrix} \quad (8)$$

$$\text{where, } \theta = \frac{1 + \sqrt{5}}{2}, \bar{\theta} = \frac{1 - \sqrt{5}}{2} = 1 - \theta, \alpha = 1 + i(1 - \theta), \bar{\alpha} = 1 + i(1 - \bar{\theta})$$

The 3D MIMO code is constructed in a hierarchical manner: eight information symbols ($\kappa = 8$) are first encoded to two Golden code words viz. $X_{Golden,1}$ and $X_{Golden,2}$, which are consequently arranged in an Alamouti manner

In equation (7), with staking of the four columns of 3D MIMO encoded matrix into one column vector matrix of size 16×1 and further staking its real and imaginary components, a vectorizing matrix $\tilde{\mathbf{X}}_{3D}$ of size 32×1 in terms of 32×16 generator matrix $\mathbf{G}$ and 16×1 real valued input signal $\tilde{\mathbf{S}}$ containing both real and imaginary components of the consecutive seven complex digitally modulated symbols can be written as:

$$\tilde{\mathbf{X}}_{3D} = \mathbf{G}\tilde{\mathbf{S}} \quad (9)$$

The generator matrix $\mathbf{G}$ is defined by:

$$\mathbf{G} \triangleq [\text{vec}(A_1), \text{vec}(B_1), \dots, \text{vec}(B_k)] \quad (10)$$

where $A_j \in \mathbb{C}^{4 \times 4}$ and $B_j \in \mathbb{C}^{4 \times 4}$ are the complex weight matrices representing the contribution of the real and imaginary parts of the j th information symbol s_j in the final codeword matrix.

If H^R and H^I denote the real and imaginary parts of channel matrix H , its complex to real converted matrix is:

$$\hat{\mathbf{H}} \triangleq \begin{bmatrix} \mathbf{H}^R & -\mathbf{H}^I \\ \mathbf{H}^I & \mathbf{H}^R \end{bmatrix} \quad (11)$$

and the equivalent channel matrix $\mathbf{H}_{eq} \in \mathbb{R}^{16 \times 16}$ is given by

$$\mathbf{H}_{eq} = (\mathbf{I}_{4 \times 4} \otimes \hat{\mathbf{H}}) \mathbf{G} \quad (12)$$

where, the operator $\otimes$ is indicative of Kronecker product

IV. ML decoding aided MIMO Signal detection

In perspective of ML decoding aided MIMO Signal detection, the real and imaginary parts of the transmitted and received signals are separated and the columns of the codeword are stacked. The received MIMO signal of Equation (6) can be expressed in an equivalent real-valued form:

$$\tilde{\mathbf{y}} = \mathbf{H}_{eq} \tilde{\mathbf{s}} + \tilde{\mathbf{n}} \quad (13)$$

where, $\tilde{\mathbf{n}}$ is the vectorizing matrix of noise term $\mathbf{N}$. On **QR** decomposition of matrix $\mathbf{H}_{eq}$ and multiplying $\tilde{\mathbf{y}}$ with conjugate transposed of matrix $\mathbf{Q}$, we would get a 16×1 real valued signal vector

$$\tilde{\mathbf{z}} = \mathbf{Q}^T \tilde{\mathbf{y}} \quad (14)$$

The matrix $\mathbf{R}$ is a 16×16 upper triangular matrix. The real ($S_{1R} \dots S_{8R}$) and imaginary ($S_{1I} \dots S_{8I}$) components of various transmitted consecutive symbols are estimated with first through 16th elements of $\tilde{\mathbf{z}}$ [$\tilde{z}(1) \dots \tilde{z}(16)$] and the elements of $\mathbf{R}$ with first through 16th rows and first through 16th columns [$R(1,1) \dots R(16,16)$]. The QAM digitally modulated four symbols are generated in MATLAB notation using **qammod(0:3,4)** and the symbols are given by:

$$[\text{QAM}] = [-1.0000 + 1.0000i \quad -1.0000 - 1.0000i \quad 1.0000 + 1.0000i \quad 1.0000 - 1.0000i]$$

The estimated imaginary components are estimated in terms of various elements of $\tilde{\mathbf{z}}$ and $\mathbf{R}$ as:

$$\begin{aligned} S_{8I} &= \tilde{z}(16) / R(16,16) \\ S_{7I} &= (\tilde{z}(15) - R(15,16) * S_{8I}) / R(15,1) \\ S_{6I} &= (\tilde{z}(14) - R(14,15) * S_{8I} - R(14,16) * S_{7I}) / R(14,14) \\ S_{5I} &= (\tilde{z}(13) - R(13,14) * S_{6I} - R(13,15) * S_{7I} - R(13,16) * S_{8I}) / R(13,13) \\ S_{4I} &= (\tilde{z}(12) - R(12,13:16) * d) / R(12,12) \\ S_{3I} &= (\tilde{z}(11) - R(11,12:16) * [S_{4I}; d]) / R(11,11) \\ S_{2I} &= (\tilde{z}(10) - R(10,11:16) * [S_{3I}; S_{4I}; d]) / R(10,10) \\ S_{1I} &= (\tilde{z}(9) - R(9,10:16) * [S_{2I}; S_{3I}; S_{4I}; d]) / R(9,9) \end{aligned} \quad (15)$$

In all cases, if $S_{iI} > 0$, $S_{iI} = 1$ and if $S_{iI} < 0$, $S_{iI} = -1$, $i=1,2,3,\dots,8$

The column vectors $\mathbf{c}$ and $\mathbf{d}$ are computed from the estimated imaginary components as

$$\mathbf{c} = \begin{bmatrix} S_{1I} \\ S_{2I} \\ S_{3I} \\ S_{4I} \end{bmatrix} \text{ and } \mathbf{d} = \begin{bmatrix} S_{5I} \\ S_{6I} \\ S_{7I} \\ S_{8I} \end{bmatrix} \quad (16)$$

The estimated real components are:

$$\begin{aligned} S_{8R} &= (\tilde{z}(8) - R(8,9:16) * [\mathbf{c}; \mathbf{d}]) / R(8,8) \\ S_{7R} &= (\tilde{z}(7) - R(7,8:16) * [S_{8R}; \mathbf{c}; \mathbf{d}]) / R(7,7) \\ S_{6R} &= (\tilde{z}(6) - R(6,7:16) * [S_{7R}; S_{8R}; \mathbf{c}; \mathbf{d}]) / R(6,6) \\ S_{5R} &= (\tilde{z}(5) - R(5,6:16) * [S_{6R}; S_{7R}; S_{8R}; \mathbf{c}; \mathbf{d}]) / R(5,5) \\ S_{4R} &= (\tilde{z}(4) - R(4,5:16) * [\mathbf{b}; \mathbf{c}; \mathbf{d}]) / R(4,4) \end{aligned} \quad (17)$$

$$S_{3R} = (\tilde{z}(3) - R(3,4:16) * [S_{4R}; b; c; d]) / R(3,3)$$

$$S_{2R} = (\tilde{z}(2) - R(2,3:16) * [S_{3R}; S_{4R}; b; c; d]) / R(2,2)$$

$$S_{1R} = (\tilde{z}(1) - R(1,2:16) * [S_{2R}; S_{3R}; S_{4R}; b; c; d]) / R(1,1)$$

In all cases, if $S_{iR} > 0$, $S_{iR} = 1$ and if $S_{iR} < 0$, $S_{iR} = -1$, $i=1,2,3,\dots,8$

$$\text{and } b = \begin{bmatrix} S_{5R} \\ S_{6R} \\ S_{7R} \\ S_{8R} \end{bmatrix} \quad (18)$$

The detected eight consecutive symbols are [14]:

$$\begin{aligned} \hat{S}_1 &= S_{1R} + \sqrt{-1} * S_{1I}; \hat{S}_2 = S_{2R} + \sqrt{-1} * S_{2I}; \hat{S}_3 = S_{3R} + \sqrt{-1} * S_{3I}; \\ \hat{S}_4 &= S_{4R} + \sqrt{-1} * S_{4I}; \hat{S}_5 = S_{5R} + \sqrt{-1} * S_{5I}; \hat{S}_6 = S_{6R} + \sqrt{-1} * S_{6I}; \\ \hat{S}_7 &= S_{7R} + \sqrt{-1} * S_{7I}; \hat{S}_8 = S_{8R} + \sqrt{-1} * S_{8I}; \end{aligned} \quad (19)$$

V. Results and Discussion

We have conducted computer simulations using MATLAB R2014a to observe critically the quality of transmitted color image in 3D MIMO encoded mmWave wireless communication system based on the parameters given in Table 1.

Table 1: Summary of the simulated model parameters

Parameters	Types
Data type	Color image
Color image size	88 pixels(height) $\times$ 96 pixels(width)
Noise reduction filter	2D median filtering
Channel coding	SPC, RA, LDPC, Convolutional, CRC and BCH
Digital modulation	QAM
Carrier frequency(GHz)	28
Antenna Configuration	4(Transmitting) $\times$ 2(Receiving)
Path loss model (dB), λ =wavelength(m) of carrier frequency, d= distance(m) between transmitter and receiver	$-20\log_{10}(\lambda / (4 \pi d))$
Number of channel paths(Cluster)	6
Number of sub paths in each Cluster	20
Base Station per path Angle Spread	5°
Mobile Station per path Angle Spread	35°
Space-time space code	3D MIMO
SNR	0-10 dB
Channel	AWGN and mmWave

With our utilized various channel coding and merely QAM digital modulation schemes, it is observable that the BER curves depicted in Figure 1 through Figure 4 are clearly indicative of showing prominent system performance. The graphical illustrations presented in Figure 1 through Figure 4 distinctly show the impact of channel concatenation. In Figure 1, the BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of individual SPA, Repeat and Accumulate channel coding and their concatenated form has been presented. At low SNR value region, the system shows worst performance in Repeat and Accumulate channel coding and satisfactory performance in concatenated channel coding over a significant low SNR value region. At a typically assumed SNR value of 1dB, the estimated BER values are 0.0553 and 0.1095 in case concatenated channel coding and Repeat and Accumulate channel coding which implies a system performance improvement of 2.97 dB. At 4% BER, a SNR gain of approximately 5.3 dB is achieved at concatenated channel coding as compared to SPA channel coding. In Figure 2, the system shows worst performance in CRC channel coding as compared to LDPC and its channel concatenation with CRC. At a typically assumed SNR value of 1dB, the estimated BER values are 0.0163 and 0.0755 in case of concatenated channel coding and CRC channel coding which implies a system performance improvement of 6.66 dB. In Figure 3, the system shows well defined system performance in BCH, AES block cipher aided channel coding and its concatenated channel coding with BCH. At a typically assumed SNR value of 1dB, the

estimated BER values are 0.0303 and 0.1821 in case of concatenated channel coding and BCH channel coding which is indicative of a system performance improvement of 7.79 dB. In Figure 4, the impact of all channel concatenation to evaluate the 3D MIMO encoded 4 x 2 mmWave wireless communication system has been shown. The simulated system shows satisfactory performance in concatenated channel coding with LDPC and Convolutional as compared to LDPC and Repeat and Accumulate channel coding. At a typically assumed SNR value of 1dB, the estimated BER values are 0.0285 and .0933 in case of concatenated channel coding with LDPC and Convolutional as compared to LDPC and Repeat and Accumulate channel coding with an achievement of system performance improvement of 5.15 dB. At 2% BER, SNR gain of approximately 3dB, 1.5 dB and 0.3dB are achieved in concatenated channel coding with LDPC and Convolutional as compared to concatenated channel coding with LDPC and Repeat and Accumulate, concatenated channel coding with LDPC and AES block cipher aided and concatenated channel coding with LDPC and SPA respectively. In Figure 5, the estimated bit error rate in transmitting color image at SNR value of 3dB is found to have a value of 0.0013. The transmitted and retrieved images with and without application of image filtering scheme and concatenated channel coding with LDPC and CRC have also been shown which provides the capability of our presently considered simulated system.

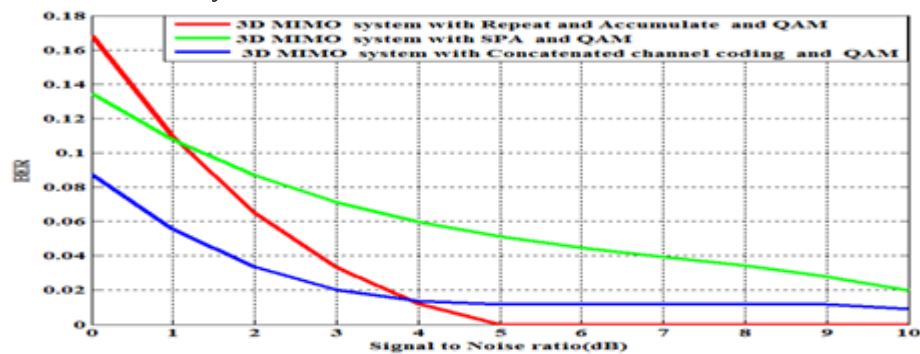


Figure 1: BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of SPA, Repeat and Accumulate and Concatenated channel coding with SPA, Repeat and Accumulate and QAM digital modulation schemes

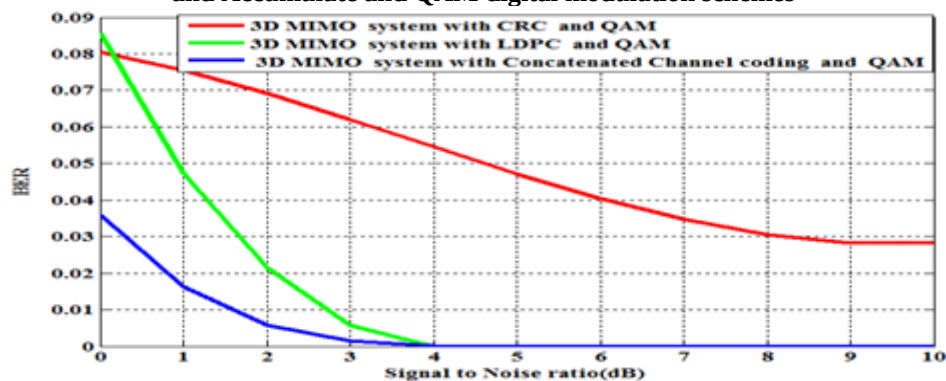


Figure 2: BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of CRC, LDPC and Concatenated channel coding with CRC and LDPC and QAM digital modulation schemes

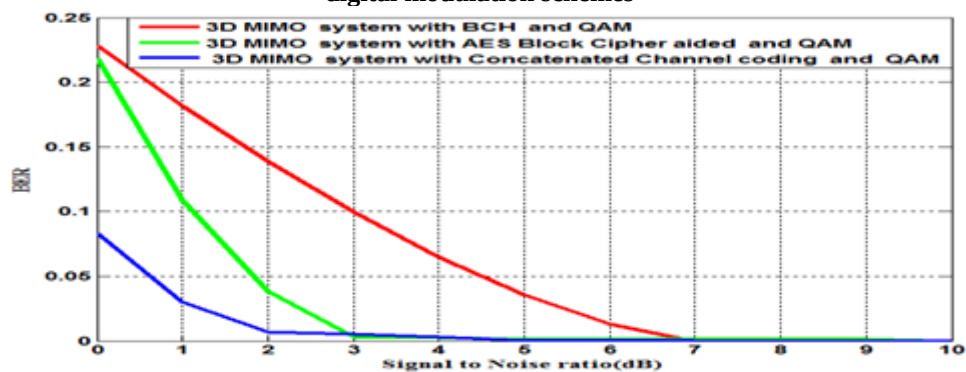


Figure 3: BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of BCH and AES Block Cipher aided and Concatenated channel coding with BCH and AES Block Cipher aided and QAM digital modulation schemes

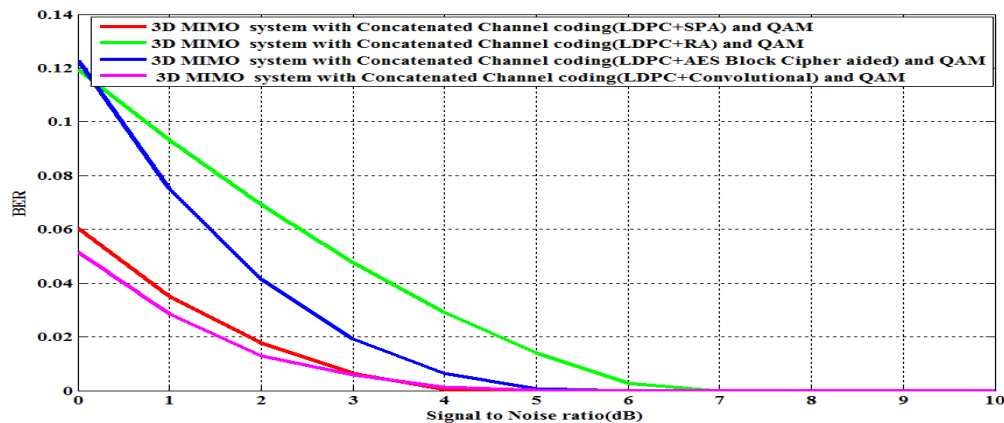


Figure 4: BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of various Concatenated channel coding and QAM digital modulation schemes

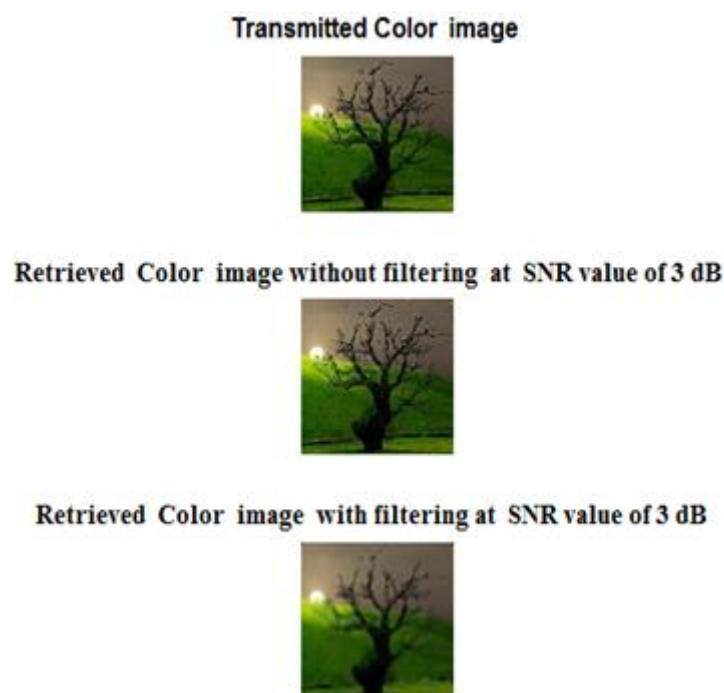


Figure 5: Transmitted and retrieved color images at 3 dB SNR value.

VI. Conclusion

In this present paper, we made BER performance evaluative study for a simulated 4 x 2 mmWave wireless communication system. The goal of such study was to implement 3D MIMO STBC encoding scheme under utilization of various channel coding schemes in individual and concatenated structural form. From the outcome of simulation results, it can be concluded that the presently considered 3D MIMO encoded 4 x 2 mmWave wireless communication system is undoubtedly a robust system in perspective of color image transmission over hostile fading channel under implementation of QAM digital modulation and concatenated channel coding scheme with LDPC and Convolutional.

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