Secure voice frequency signal transmission in 3D MIMO encoded 4 x 2 mmWave wireless communication   system

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Abstract - In this paper, we made a comprehensive BER performance simulative study on encrypted voice frequency signal transmission in a 3D MIMO encoded 4 x 2 mmWave 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), Bose–Chaudhuri–Hocquenghem(BCH), low-density parity check (LDPC), AES Block Cipher aided and ½-rated Convolutional. Based on the simulation result with MATLAB, it is quite noticeable that the simulated system is highly robust in retrieving transmitted data under mmWave MIMO fading channel in QAM digital modulation and LDPC channel coding schemes.

Index Term - 3D MIMO, modern and classical channel coding schemes,, Bit Error rate (BER), AWGN and mmWave MIMO channel

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1. Introduction

Wireless communication has become pervasive in our world and is acting as a transformative medium allowing our work, education, and entertainment to be transported without any physical connection. With tremendous development in telecommunication sector, it is being observed that nearly 50% of the traffic in cellular networks today is video. 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. 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. The mmWave wireless communication can be treated as an enabling technology that has myriad applications to existing and emerging wireless networking deployments. The first step in a mmWave communications revolution is 60 GHz 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. 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 Data centers. Future users of wireless devices will greatly benefited from the pervasive availability of massive bandwidths at mmWave frequencies. Multi-Gbps data transfers will enable a lifetime of content to be downloaded on-the-fly as users walk or drive in their daily lives**[1-3]**

In this present paper, an effort has been made to study the performance of a simulated mmWave wireless communication under utilization of a   robust and efficient space-time block coding scheme (3D MIMO).

2. System Model and Signal detection

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 a segment of recoded audio signal, the data are channel coding using various channel coding schemes discussed briefly in preceding section and subsequently interleaved   prior to converted into block wise digitally modulated complex symbols consisting of eight consecutive symbols s_1, s_2 ....s_8. The 3D MIMO code can explicitly written as:

$$X_{3D} = \begin{bmatrix} X_{Golden,1} - X^*_{Golden,2} \\ X_{Golden,2} \quad X^*_{Golden,1} \end{bmatrix} = \frac{1}{\sqrt{5}} \begin{bmatrix} \alpha(s_1 + \theta s_2) & \alpha(s_3 + \theta s_4) & -\alpha^*(s_5 + \theta s_6) & -\alpha^* s_7 + \theta s_8) \\ i\overline{\alpha}(s_3 + \overline{\theta} s_4) & \overline{\alpha}(s_1 + \overline{\theta} s_2) & i\overline{\alpha}^*(s^*_7 + \overline{\theta} s^*_8) & -\overline{\alpha}^*(s^*_5 + \overline{\theta} s^*_6) \\ \alpha(s_5 + \theta s_6) & \alpha(s_7 + \theta s_8) & \alpha^*(s^*_1 + \theta s^*_2) & \alpha^*(s^*_3 + \theta s^*_4) \\ i\overline{\alpha}(s_7 + \overline{\theta} s_8) & \overline{\alpha}(s_5 + \overline{\theta} s_6) & -i\overline{\alpha}^*(s^*_3 + \overline{\theta} s^*_4) & \overline{\alpha}^*(s^*_1 + \overline{\theta} s^*_2) \end{bmatrix} \tag{1}$$

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

The 3D MIMO code is constructed in a hierarchical manner: eight information symbols ($\kappa = 8$) are first encoded to two Golden code words viz. . XGolden,1 and XGolden,2, which are consequently arranged in an Alamouti manner[4,5].

In mmWave MIMO fading channel with N_t transmitting and N_r receiving antennas, it is expected that such channel M_{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 H_{mmw} can be written with consideration of path loss ρ as:

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

where, α_{il} is the complex gain of the i-th path in the l-th cluster which follows $CN(0,1)$. 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

$$E\{\|H_{mmw}\|_F^2\} = N_t N_r$$

where , $\|\bullet\|_F$ is the Frobenius norm and the normalized mmWave channel H is obtained through multiplication of H_{mmw} with normalization factor γ such that

$$H = \gamma H_{mmw} \tag{3}$$

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

$$a_{BS}(\varphi_{il}) = \frac{1}{\sqrt{N_t}}[1, e^{j\frac{2\pi}{\lambda}d\sin(\varphi_{il})}, \ldots\ldots e^{j(N_t-1)\frac{2\pi}{\lambda}d\sin(\varphi_{il})}]^T \tag{4}$$

and

$$a_{MS}(\theta_{il}) = \frac{1}{\sqrt{N_r}}[1, e^{j\frac{2\pi}{\lambda}d\sin(\theta_{il})}, \ldots\ldots e^{j(N_r-1)\frac{2\pi}{\lambda}d\sin(\theta_{il})}]^T \tag{5}$$

where, λ is the signal wavelength and d is the distance between two consecutive antenna elements.[6,7]

The signal model in terms of received signal $Y \in C^{2\times4}$, mmWave MIMO channel coefficient $H \in C^{2\times4}$, the 3D MIMO encoded signal(X_{3D}) transmitted in four time slots $X \in C^{4\times4}$ and the complex valued AWGN component $N \in C^{2\times4}$ can be written in matrix form as:

$$Y = HX + N \tag{6}$$

In equation (1), 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 $\tilde{X}_{3D}$ of size 32×1 in terms of 32×16 generator matrix G and 16×1 real valued input signal $\tilde{S}$ containing both real and imaginary components of the consecutive seven complex digitally modulated symbols can be written as:

$$\tilde{X}_{3D} = G\tilde{s} \qquad (7)$$

The generator matrix G is defined by:

$$\mathbf{G} \triangleq [\ vec(A_1),\ vec(B_1)\ ....\ vec(B_k)\ ] \qquad (8)$$

Where $A_j \in C^{4\times4}$ and $B_j \in C^{4\times4}$ are the complex weight matrices representing the contribution of the real and imaginary parts of the jth 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:

$$\hat{H} \triangleq \begin{bmatrix} H^R & -H^I \\ H^I & H^R \end{bmatrix} \qquad (9)$$

and the equivalent channel matrix $H_{eq} \in \Re^{16\times16}$ is given by

$$H_{eq} = (I_{4\times4} \otimes \hat{H})G \qquad (10)$$

In Equation(10), the operator $\otimes$ is indicative of Kronecker product. Separating the real and imaginary parts of the transmitted and received signals, and stacking the columns of the codeword, the received MIMO signal of Equation (6) can be expressed in an equivalent real-valued form:

$$\tilde{y} = H_{eq}\tilde{s} + \tilde{n} \qquad (11)$$

where, $\tilde{n}$ is the vectorizing matrix of noise term N. On QR decomposition of H_{eq} and multiplying $\tilde{y}$ with conjugate transposed of matrix Q, we would get a 16×1 real valued signal vector $\tilde{z} = Q^T \tilde{y}$ (12)

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

[QPSK]=[1.0000 + 0.0000i   0.0000 + 1.0000i   -1.0000 + 0.0000i   -0.0000 - 1.0000i]
   and
[QAM] = [-1.0000 + 1.0000i   -1.0000 - 1.0000i   1.0000 + 1.0000i   1.0000 - 1.0000i]
   The estimated imaginary components are:

$$S_{8I} = \tilde{z}(16)\ /\ R(16,16) = \begin{bmatrix} \textbf{QAM} \\ 1\ \text{if } S_{8I} \rangle 0 \\ -1\ \text{if } S_{8I} \langle 0 \\ \textbf{QPSK} \\ 1\ \text{if } S_{8I} \rangle 0.8 \\ -1\ \text{if } S_{8I} \langle -0.8 \\ 0\ \text{if } S_{8I} \rangle -0.4 \text{ and } S_{8I} \langle 0.4 \end{bmatrix} \qquad (13)$$

$$S_{7I} = (\tilde{z}(15) - R(15,16)*S_{8I})/R(15,15) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{7I} \rangle 0 \\ -1 \ \text{if} S_{7I} \langle 0 \\ \textbf{QPSK} \\ 1 \ \text{if } S_{7I} \rangle 0.8 \\ -1 \ \text{if} S_{7I} \langle -0.8 \\ 0 \ \text{if } S_{7I} \rangle -0.4 \text{ and } S_{7I} \langle 0.4 \end{bmatrix} \quad (14)$$

$$S_{6I} = (\tilde{z}(14) - R(14,15)*S_{8I} - R(14,16)*S_{7I})/R(14,14) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{6I} \rangle 0 \\ -1 \ \text{if} S_{6I} \langle 0 \\ \textbf{QPSK} \\ 1 \ \text{if } S_{6I} \rangle 0.8 \\ -1 \ \text{if} S_{6I} \langle -0.8 \\ 0 \ \text{if } S_{6I} \rangle -0.4 \text{ and } S_{6I} \langle 0.4 \end{bmatrix} \quad (15)$$

$$S_{5I} = (\tilde{z}(13) - R(13,14)*S_{6I} - R(13,15)*S_{7I} - R(13,16)*S_{8I})/R(13,13)) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{5I} \rangle 0 \\ -1 \ \text{if} S_{5I} \langle 0 \\ \textbf{QPSK} \\ 1 \ \text{if } S_{5I} \rangle 0.8 \\ -1 \ \text{if} S_{5I} \langle -0.8 \\ 0 \ \text{if } S_{5I} \rangle -0.4 \text{ and } S_{5I} \langle 0.4 \end{bmatrix} \quad (16)$$

$$S_{4I} = (\tilde{z}(12) - R(12,13:16)*d)/R(12,12) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{4I} \rangle 0 \\ -1 \ \text{if} S_{4I} \langle 0 \\ \textbf{QPSK} \\ 1 \ \text{if } S_{4I} \rangle 0.8 \\ -1 \ \text{if} S_{4I} \langle -0.8 \\ 0 \ \text{if } S_{4I} \rangle -0.4 \text{ and } S_{4I} \langle 0.4 \end{bmatrix} \quad (17)$$

$$S_{3I} = (\tilde{z}(11) - R(11,12:16)*[S_{4I};d]) / R(11,11) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{3I} \rangle 0 \\ -1 \ \text{if} S_{3I} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ \text{if } S_{3I} \rangle 0.8 \\ -1 \ \text{if} S_{3I} \langle -0.8 \\ \quad 0 \ \text{if } S_{3I} \rangle -0.4 \ \text{and} \ S_{3I} \ \langle 0.4 \end{bmatrix} (18)$$

$$S_{2I} = (\tilde{z}(10) - R(10,11:16)*[S_{3I};S_{4I};d]) / R(10,10) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{2I} \rangle 0 \\ -1 \ \text{if} S_{2I} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ \text{if } S_{2I} \rangle 0.8 \\ -1 \ \text{if} S_{2I} \langle -0.8 \\ \quad 0 \ \text{if } S_{2I} \rangle -0.4 \ \text{and} \ S_{2I} \ \langle 0.4 \end{bmatrix} (19)$$

$$S_{1I} = (\tilde{z}(9) - R(9,10:16)*[S_{2I};S_{3I};S_{4I};d]) / R(9,9 = \begin{bmatrix} \textbf{QAM} \\ 1 \ \text{if } S_{1I} \rangle 0 \\ -1 \ \text{if} S_{1I} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ \text{if } S_{1I} \rangle 0.8 \\ -1 \ \text{if} S_{1I} \langle -0.8 \\ \quad 0 \ \text{if } S_{1I} \rangle -0.4 \ \text{and} \ S_{1I} \ \langle 0.4 \end{bmatrix} (20)$$

The column vectors c and d are computed from the estimated imaginary components as

$$c = \begin{bmatrix} S_{1I} \\ S_{2I} \\ S_{3I} \\ S_{4I} \end{bmatrix} \quad \text{and} \quad d = \begin{bmatrix} S_{5I} \\ S_{6I} \\ S_{7I} \\ S_{8I} \end{bmatrix} \tag{21}$$

The estimated real components are:

$$S_{8R} = (\tilde{z}(8) - R(8,9:16)*[c;d]) / R(8,8) = \begin{bmatrix} \textbf{QAM} \\ 1 \ if \ S_{8R} \rangle 0 \\ -1 \ if S_{8R} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ if \ S_{8I} \rangle 0.8 \\ -1 \ if S_{8I} \langle -0.8 \\ \quad -0.0 \ if \ S_{8I} \rangle -0.2 \ and \ S_{8I} \langle 0.0 \end{bmatrix}$$

(22)

$$S_{7R} = (\tilde{z}(7) - R(7,8:16)*[S_{8R};c;d]) / R(7,7) = \begin{bmatrix} \textbf{QAM} \\ 1 \ if \ S_{7R} \rangle 0 \\ -1 \ if S_{7R} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ if \ S_{7I} \rangle 0.8 \\ -1 \ if S_{7I} \langle -0.8 \\ \quad -0.0 \ if \ S_{7I} \rangle -0.2 \ and \ S_{7I} \langle 0.0 \end{bmatrix}$$

(23)

$$S_{6R} = (\tilde{z}(6) - R(6,7:16)*[S_{7R};S_{8R};c;d]) / R(6,6) = \begin{bmatrix} \textbf{QAM} \\ 1 \ if \ S_{6R} \rangle 0 \\ -1 \ if S_{6R} \langle 0 \\ \textbf{QPSK} \\ \quad 1 \ if \ S_{6I} \rangle 0.8 \\ -1 \ if S_{6I} \langle -0.8 \\ \quad -0.0 \ if \ S_{6I} \rangle -0.2 \ and \ S_{6I} \langle 0.0 \end{bmatrix}$$

(24)

$$
S_{5R} = (\tilde{z}(5) - R(5,6:16)*[S_{6R}\,;S_{7R}\,;S_{8R}\,;c;d]) / R(5,5) =
\begin{bmatrix}
\textbf{QAM} \\
1 \ \text{if } S_{5R} \rangle 0 \\
-1 \ \text{if} S_{5R} \langle 0 \\
\textbf{QPSK} \\
\quad 1 \ \text{if } S_{5I} \rangle 0.8 \\
-1 \ \text{if} S_{5I} \langle -0.8 \\
\quad -0.0 \ \text{if } S_{5I} \rangle -0.2 \ \text{and} \ S_{5I} \langle 0.0
\end{bmatrix}
$$

(25)

$$
S_{4R} = (\tilde{z}(4) - R(4,5:16)*[b;c;d]) / R(4,4) =
\begin{bmatrix}
\textbf{QAM} \\
1 \ \text{if } S_{4R} \rangle 0 \\
-1 \ \text{if} S_{4R} \langle 0 \\
\textbf{QPSK} \\
\quad 1 \ \text{if } S_{4I} \rangle 0.8 \\
-1 \ \text{if} S_{4I} \langle -0.8 \\
\quad -0.0 \ \text{if } S_{4I} \rangle -0.2 \ \text{and} \ S_{4I} \langle 0.0
\end{bmatrix}
$$

(26)

$$
S_{3R} = (\tilde{z}(3) - R(3,4:16)*[S_{4R}\,;b;c;d]) / R(3,3) =
\begin{bmatrix}
\textbf{QAM} \\
1 \ \text{if } S_{3R} \rangle 0 \\
-1 \ \text{if} S_{3R} \langle 0 \\
\textbf{QPSK} \\
\quad 1 \ \text{if } S_{3I} \rangle 0.8 \\
-1 \ \text{if} S_{3I} \langle -0.8 \\
\quad -0.0 \ \text{if } S_{3I} \rangle -0.2 \ \text{and} \ S_{3I} \langle 0.0
\end{bmatrix}
$$

(27)

$$
S_{2R} = (\tilde{z}(2) - R(2,3:16)*[S_{3R}\,;S_{4R}\,;b;c;d]) / R(2,2) =
\begin{bmatrix}
\textbf{QAM} \\
1 \ \text{if } S_{2R} \rangle 0 \\
-1 \ \text{if} S_{2R} \langle 0 \\
\textbf{QPSK} \\
\quad 1 \ \text{if } S_{2I} \rangle 0.8 \\
-1 \ \text{if} S_{2I} \langle -0.8 \\
\quad -0.0 \ \text{if } S_{2I} \rangle -0.2 \ \text{and} \ S_{2I} \langle 0.0
\end{bmatrix}
$$

(28)

$$S_{1R} = (\tilde{z}(1) - R(1,2:16)*[S_{2R};S_{3R};S_{4R};b;c;d])/R(1,1) = \begin{bmatrix} \textbf{QAM} \\ 1 \ \ \text{if } S_{1R} > 0 \\ -1 \ \ \text{if} S_{1R} < 0 \\ \textbf{QPSK} \\ \ \ 1 \ \ \text{if } S_{1I} > 0.8 \\ -1 \ \ \text{if} S_{1I} < -0.8 \\ \ -0.0 \ \ \text{if } S_{1I} > -0.2 \ \text{and} \ \ S_{1I} \ < 0.0 \end{bmatrix}$$

$$(29)$$

$$where, b = \begin{bmatrix} S_{5R} \\ S_{6R} \\ S_{7R} \\ S_{8R} \end{bmatrix} \qquad (30)$$

The detected eight consecutive symbols   are:

$$\hat{S}_1 = S_{1R} + sqrt(-1)*S_{1I}; \ \hat{S}_2 = S_{2R} + sqrt(-1)*S_{2I}; \ \hat{S}_3 = S_{3R} + sqrt(-1)*S_{3I};$$

$$\hat{S}_4 = S_{4R} + sqrt(-1)*S_{4I}; \ \hat{S}_5 = S_{5R} + sqrt(-1)*S_{5I}; \hat{S}_6 = S_{6R} + sqrt(-1)*S_{6I};$$

$$\hat{S}_7 = S_{7R} + sqrt(-1)*S_{7I}; \ \hat{S}_8 = S_{8R} + sqrt(-1)*S_{8I};$$

$$(31)$$

3. Channel Coding

Various channel coding techniques such CRC, BCH, LDPC, AES Block Cipher aided   and   Convolutional have been used in this paper. A brief overview is outlined below.

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 ½ 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[8]

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

$$(32)$$

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[9]. In LDPC (Low density parity-check matrix) coding, ½-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] is 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 $[\mathbf{u}]=[u_1u_2u_3u_4\ldots\ldots.u_{512}]^T$ and three matrices [P](of [newH]),[L] and [U]   using the following Matlab notation :

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

The LDPC encoded 1024× 1 sized block based binary data sequence [c] is formulated from concatenation of parity check bit $\mathbf{p}$ and information bit $\mathbf{u}$ 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[10,11].

 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 [12,13].

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 [14].

4. Results and Discussion

We have conducted computer simulations using MATLAB **R2014a** to to observe critically the quality of transmitted voice frequency signal transmission 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	Audio signal
No. of samples	8192
Sampling Frequency(Hz)	8000
No of binary bits for a single sample	8
Total number of binary bits from audio samples	65536
Total number of 3D MIMO encoded codeword block	8192
Digital modulation	QPSK and QAM
Carrier frequency(GHz)	28
Antenna Configuration	4(Transmitting) × 2(Receiving)
Path loss model (dB), λ =wavelength(m) of carrier frequency, d= distance(m) between transmitter and receiver	-20$\log_{10}$(λ /(4 π d)
Number of channel paths(Cluster)	6
Number of sub paths in each Cluster	20
Base Station per path Angle Spread	5^0
Mobile Station per path Angle Spread	35^0
Space-time space code	3D MIMO
SNR	0-10 dB
Channel	AWGN and mmWave

It is noticeable that the BER curves depicted in Figure 2 through Figure 5 are clearly indicative of showing distinct system performance under various channel coding and low order digital modulation schemes. In all cases, the simulated system shows almost satisfactory performance in QAM and worst performance in QPSK digital modulation. In Figure 2 , BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of 1/2-rated Convolutional, Repeat and Accumulate channel coding as well as QAM and QPSK digital modulation schemes are presented . It is quite obvious that the system performance is quite satisfactory with Repeat and Accumulate channel coding. At a typically assumed SNR value of 1dB, the estimated BER values are 0.0456 and 0.1022 in case of Repeat and Accumulate with QAM and 1/2-rated Convolutional with QPSK digital modulation which implies reasonable system

performance improvement of **3.51** dB in Repeat and Accumulate channel coding as compared to 1/2-rated Convolutional. At 2% BER, a SNR gain of approximately 3 .75 dB is achieved at . Repeat and Accumulate with QAM as compared to 1/2-rated Convolutional with QPSK. In Figure 3 , the BER performance of the simulated system under utilization of LDPC and BCH channel coding as well as low order digital modulation schemes is very much well defined and distinct. At 1 dB SNR value, the estimated BER values are found to have values of 0.0331 and 0.2491 in case of LDPC with QAM and BCH with QPSK which is indicative a quite satisfactory and acceptable system performance improvement of **8.77** dB. At 5% BER, a SNR gain of approximately 5.2 dB is achieved at LDPC with QAM as compared to BCH with QPSK. In Figure 4, it is observable that the BER performance of the simulated system improves almost linearly with increase in SNR values over a significant portion of SNRs under consideration of QAM with AES Block Cipher aided and CRC channel coding schemes. At low SNR value, the system performance with AES Block Cipher aided channel coding and QPSK is quite unsatisfactory and worst. At 1 dB SNR value, the estimated BER values are found to have values of 0.1583 and 0.2579 in case of AES Block Cipher aided channel coding with QAM and with QPSK which is indicative a quite satisfactory and acceptable system performance improvement of **2.12** dB. In Figure 5, the transmitted and retrieved audio signals at 2dB and 5dB are presented . Such presentation clearly indicates that the retrieved signal is highly distorted in 2dB SNR value. In Figure 6, presented graphs for spectral

analysis of transmitted and retrieved audio signals at 2dB and 5 dB SNR values at various angular frequencies(0 Hz to 25 kHz which corresponds to linear frequency: 0 Hz to 3.9789k Hz) clearly indicate that at 2dB SNR value, significant reduction of frequency components in the retrieved audio signal occurs . On the other hand, the frequency components of the retrieved audio signal at 5dB SNR value have great resemblance with those present in the original transmitted audio signal.
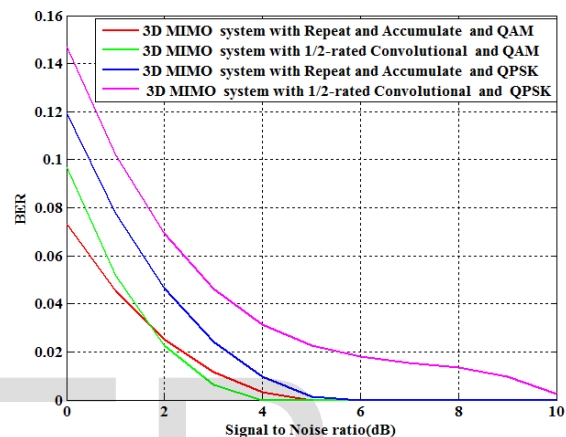

Fig. 2. BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of 1/2-rated Convolutional, Repeat and Accumulate channel coding and low order digital modulation schemes
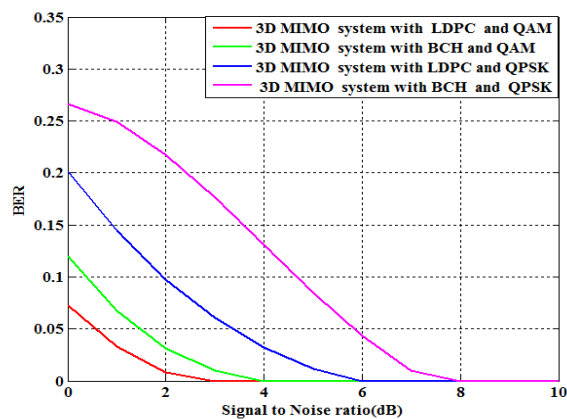

Fig. 3. BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of LDPC , BCH channel coding and low order digital modulation schemes
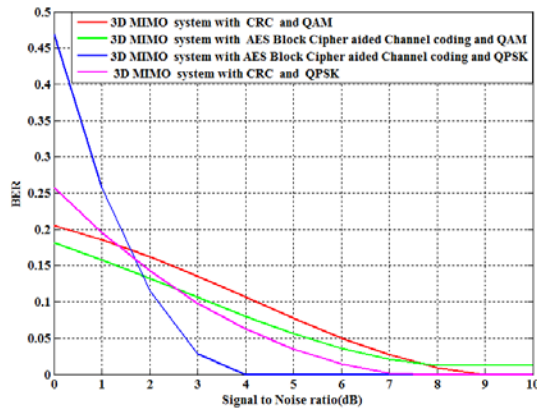
Fig. 4. BER performance of 3D MIMO encoded 4 x 2 mmWave wireless communication system under utilization of CRC , AES Block Cipher based channel coding and low order digita modulation schemes
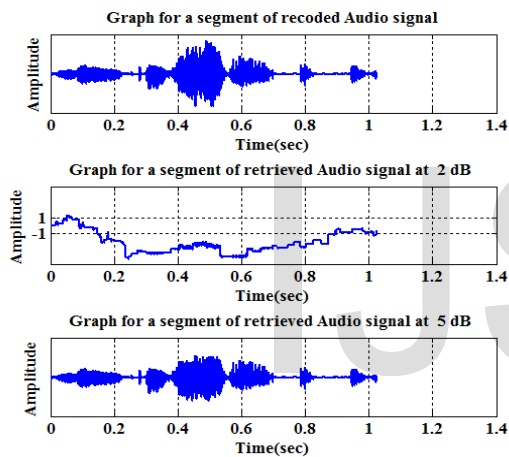

Fig.5. Transmitted and retrieved audio signals in 3D MIMO encoded 4 x 2 mmWave wireless communication system
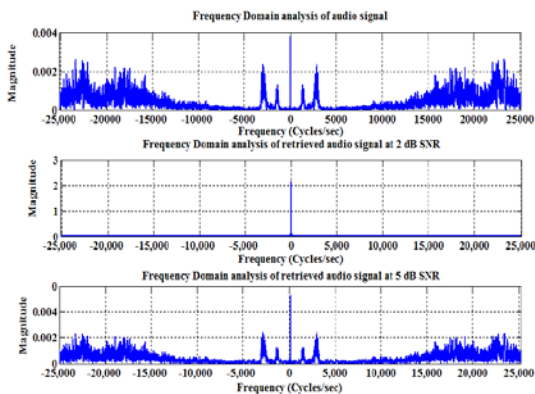

Fig.6. Graphical illustrations showing spectral analysis of Transmitted and retrieved audio signals in 3D

MIMO encoded 4 x 2 mmWave wireless communication system

5. CONCLUSION

In this present paper, we have tried to make a comprehensive study on the performance analysis of 4 x 2 mmWave wireless communication system. The goal of such simulation study was to implement 3D MIMO STBC encoding scheme under utilization of low order digital modulation and various and channel coding schemes. 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 audio signal transmission in hostile fading channel under implementation of QAM digital modulation and LDPC channel coding schemes.

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