Video Signal Transmission In 3D MIMO Encoded 4 X 2 mmWave Wireless Communication System

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***Abstract*—In this paper, robustness and effectiveness of 3D MIMO space-time block coding scheme have been evaluated in 3D MIMO encoded 4 x 2 mmWave wireless communication system on video signal transmission. The simulated system utilizes two channel coding schemes such as such as Repeat and Accumulate(RA),(3,2) single parity code(SPC) and 2-D Median filtering for noise reduction Based on the simulation result with MATLAB, it is quite noticeable that the simulated system is highly robust in retrieving video signal under mmWave MIMO fading channel in QAM digital modulation and Repeat and Accumulate channel coding scheme.**

Keywords—3D MIMO code, Channel coding ,2-D Median filtering, Bit Error rate (BER), AWGN and mmWave MIMO channel

I. Introduction

Multiple-input multiple-output (MIMO) is a promising technique which provides significant communication performance using multiple antennas both at receiver and transmitter. In combination with space-time block code (STBC), the communication system provides higher spectrum efficiency with better communication reliability. The space-time-space (3D) MIMO code was previously proposed for the future TV broadcasting systems in which the services are rendered by the MIMO transmission in a single frequency network (SFN). Such coding scheme can be proposed for a distributed MIMO broadcasting scenario where TV programs are transmitted by two geographically separated transmission sites, each site is equipped with two transmit antennas and each receiver site is equipped with two receive antennas forming a 4 × 2 MIMO transmission[1]. Recently, it is observed that a great emphasis is being given on MmWave wireless communication which is treated as an enabling technology that has myriad applications to existing and emerging wireless networking deployments. 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.For next generation(5G) Network, a massive amount of unlicensed millimeter-wave spectrum (30-300 GHz) can be exploited to meet up the ever increasing video transmission based traffic[2,3].

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

II. Signal Processing

In our study, a video file in mp4 format is downloaded from a website at https:// www.youtube.com.Each of selected video frame is decomposed into its R, G and B components and subsequently converted into binary data. The binary data are channel coded , interleaved , digitally modulated and 3D MIMO encoded prior to transmission with 4 transmit antennas over flat mmWave fading channel. In receiving end, the transmitted signals are received with 2 receive antennas and detected with ML decoding based signal detection technique. A brief overview of various channel coding, mmWave channel model, MIMO system model and MIMO signal detection schemes is given below.

A. Channel Coding

In (3,2) SPC (Single parity code) encoding scheme, the transmitted binary bits are rearranged into very small codeword , x = [x0,x1,x2] consisting of merely two consecutive bits [x0,x1] and an additional single parity bit, x2 = x0 x1 where, 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 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[4].

A. MmWave MIMO fading channel

We consider a mmWave MIMO fading channel with Nt transmitting and Nr receiving antennas, it is expected that such channel Mmmw is assumed to be the sum of all propagation paths that are scattered in Nc clusters with each cluster contributing Np paths. Under these scenario, themmWave channel 2×4 sized Hmmw can be written with consideration of path loss ρ as:

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

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 mmWavechannel H_{mmw} is normalized to satisfy

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

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

H=$F_{norm} \odot H_{mmw}$**(3)**

where, the symbol $\odot$denotes the Hadamard product and each element of F_{norm} is $1/|F_{norm}(i,j)|$ and $|F_{norm}(i,j)|$ denotes the magnitude of the (i, j)th element of F_{norm}

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

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

(4)

and

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

where, λ is the signal wavelength and d is the distance between two consecutive antenna elements[**5,6**]

B. MIMO System model

The signal model in terms of received signal $Y \epsilon C^{2\times4}$, mmWave MIMO channel coefficient $H \epsilon C^{2\times4}$, the transmitted signal $X \epsilon C^{4\times4}$ and the complex valued AWGN component $N \epsilon C^{2\times4}$ can be written in matrix form as:

$$Y=HX+N \quad (6)$$

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

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

$$\text{where, } \theta = \frac{1+\sqrt{5}}{2}, \bar{\theta} = \frac{1-\sqrt{5}}{2} = 1-\theta,\ \alpha = 1+i(1-\theta),\ \bar{\alpha} = 1+i(1-\bar{\theta}) \quad \textbf{(7)}$$

The 3D MIMO code is constructed in a hierarchical manner: eight information symbols (κ = 8) are first encoded to two Golden code words viz. . XGolden,1 and XGolden,2, which are consequently arranged in an Alamouti manner In equation (6), 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:

$$\tilde{X}_{3D} = G\tilde{s} \quad (8)$$

The generator matrix G is defined by:

$$\mathbf{G} \triangleq [\, vec(A_1), vec(B_1) \ldots\ldots\ldots\, vec(B_k)\,] \quad (9)$$

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:

$$\hat{H} \triangleq \begin{bmatrix} H^R & -H^I \\ H^I & H^R \end{bmatrix} \quad (10)$$

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

$$H_{eq} = (I_{4\times4} \otimes \hat{H})G \quad (11)$$

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

C. 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:

$$\tilde{y} = H_{eq}\tilde{s} + \tilde{n} \quad (12)$$

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

$$\tilde{z} = Q^T\tilde{y} \quad (13)$$

The real($S_{1R}....S_{8R}$) and imaginary (S_{1I} -- components of various transmitted consecutive symbols are estimated with first through 16th elements of the matrix $\tilde{z}$ [$\tilde{z}(1)....\tilde{z}(16)$] and the elements of 16×16 sized upper triangular matrix R with first through 16th rows and first through 16th columns[R(1,1) ... R(16,16)]. The QAM digitally modulated four symbols are generated in MATLAB notation and the symbols are given by:
[QAM] = [-1.0000 + 1.0000i -1.0000 - 1.0000i 1.0000 + 1.0000i 1.0000 - 1.0000i] . The estimated imaginary components are estimated in terms of various elements of $\tilde{z}$ and R as:

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

In all cases, if $S_{iI} \rangle 0, S_{iI} = 1$ and if $S_{iI} \langle 0, S_{iI}$
i=1,2,3...........8

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

$$c = \begin{bmatrix} S_{1I} \\ S_{2I} \\ S_{3I} \\ S_{4I} \end{bmatrix} \text{ and } d = \begin{bmatrix} S_{5I} \\ S_{6I} \\ S_{7I} \\ S_{8I} \end{bmatrix} \quad (15)$$

The estimated real components are:

$$S_{8R} = (\tilde{z}(8) - R(8,9:16) * [c; d])/R(8,8)$$
$$S_{7R} = (\tilde{z}(7) - R(7,8:16) * [S_{8R}; c; d])/R(7,7)$$
$$S_{6R} = (\tilde{z}(6) - R(6,7:16) * [S_{7R}; S_{8R}; c; d])/R(6,6)$$
(16)
$$S_{5R} = (\tilde{z}(5) - R(5,6:16) * [S_{6R}; S_{7R}; S_{8R}; c; d])/R(5,5)$$
$$S_{4R} = (\tilde{z}(4) - R(4,5:16) * [b; c; d])/R(4,4)$$
$$S_{3R} = (\tilde{z}(3) - R(3,4:16) * [S_{4R}; b; c; d])/R(3,3)$$
$$S_{2R} = (\tilde{z}(2) - R(2,3:16) * [S_{3R}; S_{4R}; b; c; d])/R(2,2)$$
$$S_{1R} = (\tilde{z}(1) - R(1,2:16) * [S_{2R}; S_{3R}; S_{4R}; b; c; d])/R(1,1) \quad (16)$$

In all cases, if $S_{iR} \rangle 0, S_{iR} = 1$ and if $S_{iR} \langle 0, S_{iR} = -1$, i=1,2,3...........8

$$\text{and } b = \begin{bmatrix} S_{5R} \\ S_{6R} \\ S_{7R} \\ S_{8R} \end{bmatrix} \quad \mathbf{(17)}$$

The detected eight consecutive symbols are[**1**]:

$$\hat{S}_1 = S_{1R} + \text{sqrt}(-1) * S_{1I};\ \hat{S}_2 = S_{2R} + \text{sqrt}(-1) * S_{2I};$$
$$\hat{S}_3 = S_{3R} + \text{sqrt}(-1) * S_{3I};$$
$$\hat{S}_4 = S_{4R} + \text{sqrt}(-1) * S_{4I};\ \hat{S}_5 = S_{5R} + \text{sqrt}(-1) * S_{5I} \quad (18)$$
$$\hat{S}_6 = S_{6R} + \text{sqrt}(-1) * S_{6I};$$
$$\hat{S}_7 = S_{7R} + \text{sqrt}(-1) * S_{7I};\ \hat{S}_8 = S_{8R} + \text{sqrt}(-1) * S_{8I};$$

Result 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	Values
Data Type	Video Signal
Number of frames used	8
Frame size	480 pixels(Width) and 360 pixels(Height)
Frame rate	30 frames/ sec
Carrier frequency(GHz)	28
Path loss model (dB), λ =wavelength(m) of carrier frequency, d= distance(m) between transmitter and receiver	$-20\log_{10}(\lambda/(4\pi d)$
Digital modulation	QAM
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
Noise type	Impulse (Salt and pepper) and Gaussian
Signal to Noise Ratio (SNR) in dB	0 to 10 dB
Noise reduction Filter	2-D Median filtering
Channel coding	SPC, RA, LDPC, Convolutional, CRC and BCH
Antenna Configuration	4(Transmitting) × 2(Receiving)

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Table 2: Estimated Bit error rate(BER) at SNR value of 5dB

Frame #	With Repeat and Accumulate Channel coding	With (3,2) SPC Channel coding
50	0.0929	0.1341
100	0.0997	0.0998
700	0.0954	0.1897
1050	0.156	0.1640
1600	0.0833	0.1120
1900	0.2041	0.1505
2050	0.1263	0.1485
2450	0.0815	0.1533

The transmitted eight video frames and their corresponding impulsive (salt and pepper) noise contaminated version have been presented In Figure 1 and Figure 2 respectively. The rate of noise contamination rate is 5% viz. **8640** pixels out of **172800** pixels are contaminated with impulsive noise for each 480 pixels ×360 pixels sized Red, Green and Blue components of an individual video frame. In Figure 3 and Figure4, the retrieved video frames with R and A and SPC channel coding schemes at 5 dB SNR value are presented. On critical assessment of the simulation results presented in Table 2, it is observable that the simulated system shows quite satisfactory performance in Repeat and Accumulate channel coding scheme.

In Figure 5, histograms of captured RGB to Gray converted selected 1050th video frame in transmission , receiption and noise contamination scenario are presented. The histograms are indicative of pixel intensity values(0 to 255) and the absence of intensity values in the lower range confirms that the captured 1050th video frame is not bright. The presented histogram in case of Repeat and accumulate channel coding implementation has great resemblance with the original transmited video frame. In case of salt and paper noise contamination, some intensity values in the range 50-60 are noticeable. In Figure 6, three dimensional perspective graphical illustrations for RGB toGray converted transmitted , received and salt and pepper noise contaminated sequences for a typically assumed 50th video frame have been presented which ratifies that the simulated 3D MIMO encoded 4 x 2 mmWave Wireless Communication system is very much effective in retrieving video signal under implementation of Repeat and accumulate channel equalization technique.

Figure 1: Transmitted video frames in 3D MIMO encoded 4 x 2 mmWave Wireless Communication System

Figure 2: Salt and pepper noise contaminated video frames in 3D MIMO encoded 4 x 2 mmWave Wireless Communication System

Figure 3: Received video frames in 3D MIMO encoded 4 x 2 mmWave Wireless Communication System with implementation of Repeat andAccumulate Channel coding scheme

Figure 4: Received video frames in 3D MIMO encoded 4 x 2 mmWave Wireless Communication System with implementation of (2,3) SPC Channel coding scheme

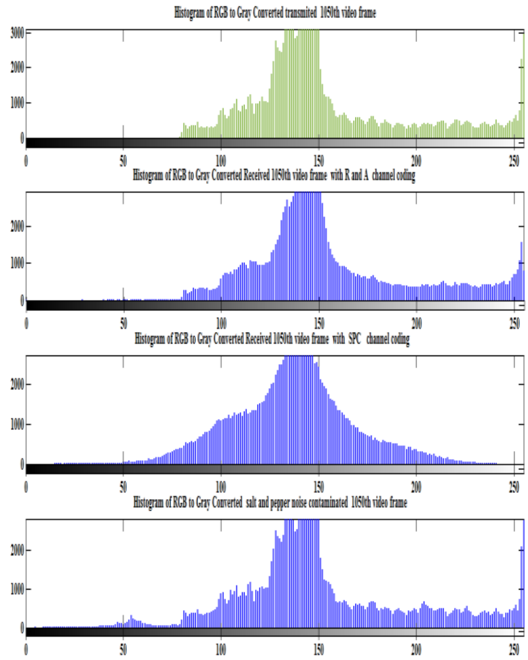

Figure 5.Histogram of RGB to Gray converted transmitted , received and salt and pepper noise contaminated sequences for a typically assumed 1050th video frame

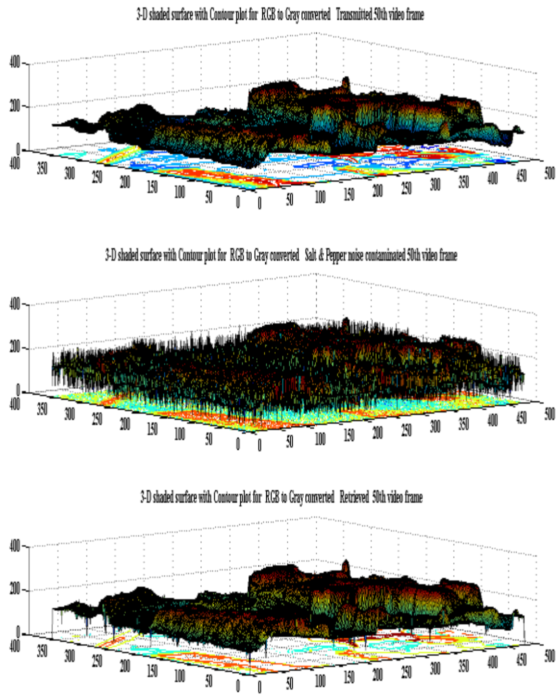

Figure 6. 3-Dimensional pictorial view of RGB to Gray converted transmitted , received and salt and pepper noise contaminated sequences for a typically assumed 50th video frame

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 Repeat and Accumulate channel coding scheme.

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