Performance Assessment of Mimo Mccdma System on Video Signal Transmission with Implementation of Various Digital Signal Processing Techniques

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Abstract: In this paper, we made a comprehensive study to evaluate the performance of MIMO MCCDMA wireless communication system on video signal transmission. The 4-by-4multi antenna supported MCCDMA system incorporates various digital signal processing techniques such as Minimum mean square error (MMSE) , Zero-Forcing (ZF), Ordered successive interference cancellation (OSIC) and Lattice Reduction aided MMSE for transmitted signal detection and two-dimensional nonlinear Median filtering for noise reduction. It is observable from MATLAB based simulations that the system shows quite satisfactory performance under scenario of MMSE signal detection scheme.

Keywords: Mimo, Mccdma, ZF, Mmse, Osic, Lr-Mmse, 2-D Median Filtering, Snr

1. Introduction

Multi Carrier CDMA(MC-CDMA) technique has become increasingly popular in wireless communications, mainly due to its high spectral efficiency, robustness to frequency selective fading and flexibility to support integrated applications. Various MC-CDMA schemes have been proposed and can be classified into two main categories based on two different ways of combining CDMA and Orthogonal Frequency Division Multiplexing (OFDM). One is to spread the original data sequence in the time domain and the other is to spread in frequency domain. The former scheme, which is so called MC-DS-CDMA has some advantages, such as easy tracking of the fading process over subcarriers. It, however, cannot achieve the frequency diversity gain, which is the main advantage of using multicarrier modulation technique. The latter scheme, which is usually called MCCDMA, can exploit frequency diversity. The Multi-Carrier Code-Division Multiple Access (MCCDMA) systems, which are capable of supporting the interworking of existing as well as future broadcast and personal communication systems[1,2]. In 2009, Antonis et.al., made a comparative study on the error rate performance of downlink coded multiple-input multiple-output multi-carrier code division multiple access (MIMO MC-CDMA) and coded MIMO orthogonal frequency division multiple access (MIMO OFDMA) systems under frequency selective fading channel conditions and showed that MIMO MC-CDMA system outperforms as compared to MIMO OFDMA system. In MC-CDMA multiplexing technique, multiple users are permitted to access the wireless channel simultaneously by modulating and spreading their input data signals across the frequency domain using different spreading sequences. In such scheme, the reliability of detecting individual user's transmitted signal is not highly dependent on the signal's strength [3,4].

In this present study, an effort has been made to observe the performance of MIMO MCCDMA system under a scenario of video signal transmission.

2. Signal Processing Techniques

We assumed that the captured video signal is preprocessed

in channel coding, digital modulation, interleaving, multicarrier CDMA encoding and spatial multiplexing schemes prior to transmission through a MIMO fading channel. The received signal $Y \in C^{4 \times 4562325}$ in terms of channel matrix $H \in C^{4 \times 4}$, transmitted signal $X \in C^{4 \times 4562325}$ and concatenated additive white Gaussian noise (AWGN) with a variance of σ_n^2 and impulsive (salt and pepper) noise $N \in C^{4 \times 4562325}$ can be written as

$$Y = HX + N \tag{1}$$

In Minimum mean square error (MMSE) based signal detection scheme, the MMSE weight matrix is given by

$$W_{MMSE} = (H^H H + \sigma_n^2 I)^{-1} H^H \tag{2}$$

Where $(.)^H$ denotes the Hermitian transpose operation and the detected desired signal $\tilde{X}_{MMSE} \in C^{4 \times 4562325}$ from the transmitting antenna is given by

$$\tilde{X}_{MMSE} = W_{MMSE} Y \tag{3}$$

In Zero-Forcing (ZF) signal detection scheme, the ZF weight matrix is given by

$$W_{ZF} = (H^H H)^{-1} H^H \tag{4}$$

and the detected desired signal $\tilde{X}_{ZF} \in C^{4 \times 4562325}$ from the transmitting antenna is given by

$$\tilde{X}_{ZF} = W_{ZF} Y \tag{5}$$

In Ordered successive interference cancellation (OSIC) signal detection scheme, its implementation is performed in four steps. In first step, the first detected signal/data stream $\tilde{X}_{OSIC-1}$ and modified form of received signal $\tilde{Y}_{OSIC-1}$ can be written as:

$$\begin{aligned} \tilde{X}_{OSIC-1} &= W_{(MMSE(1,:))} Y \\ \tilde{Y}_{OSIC-1} &= Y - H_{(:,1)} \tilde{X}_{OSIC-1} \end{aligned} \tag{6}$$

In second step, the second detected signal/data stream $\tilde{X}_{OSIC-2}$ and modified form of received signal $\tilde{Y}_{OSIC-2}$ can be written as:

$$\begin{aligned} \tilde{X}_{OSIC-2} &= W_{(MMSE(2,:))} \tilde{Y}_{OSIC-1} \\ \tilde{Y}_{OSIC-2} &= \tilde{Y}_{OSIC-1} - H_{(:,2)} \tilde{X}_{OSIC-2} \end{aligned} \tag{7}$$

In third step, the third detected signal/data stream $\tilde{X}_{OSIC-3}$ and modified form of received signal $\tilde{Y}_{OSIC-3}$ can be written as:

$$\begin{aligned} \tilde{X}_{OSIC-3} &= W_{(MMSE(3,:))} \tilde{Y}_{OSIC-2} \\ \tilde{Y}_{OSIC-3} &= \tilde{Y}_{OSIC-2} - H_{(:,3)} \tilde{X}_{OSIC-3} \end{aligned} \tag{8}$$

In fourth step, the fourth detected signal/data stream $\tilde{X}_{OSIC-4}$ and modified form of received signal $\tilde{Y}_{OSIC-4}$ can be written as:

$$\begin{aligned} \tilde{X}_{OSIC-4} &= W_{(MMSE(4,:))} \tilde{Y}_{OSIC-3} \\ \tilde{Y}_{OSIC-4} &= \tilde{Y}_{OSIC-3} - H_{(:,4)} \tilde{X}_{OSIC-4} \end{aligned} \tag{9}$$

where, $W_{(MMSE(1,:))}$, $W_{(MMSE(2,:))}$, $W_{(MMSE(3,:))}$ and $W_{(MMSE(4,:))}$ are the first, second, third and fourth rows of MMSE weight matrix and $H_{(:,1)}$, $H_{(:,2)}$, $H_{(:,3)}$, and $H_{(:,4,:)}$ are the first, second, third and fourth columns of the channel matrix respectively. The detected desired signal $\tilde{X}_{OSIC} \in C^{4 \times 4562325}$ from the transmitting antenna is given by

$$\tilde{X}_{OSIC} = \begin{bmatrix} \tilde{X}_{OSIC-1} \\ \tilde{X}_{OSIC-2} \\ \tilde{X}_{OSIC-3} \\ \tilde{X}_{OSIC-4} \end{bmatrix} \tag{10}$$

In Lattice Reduction aided MMSE signal detection technique, Lenstra-Lenstra-Lovasz (LLL) algorithm is implemented. Under such algorithm implementation scenario, the channel matrix H is transformed into a 8×8 real -valued matrix H_{real} as:

$$H_{real} = \begin{bmatrix} \Re(H) & -\Im(H) \\ \Im(H) & \Re(H) \end{bmatrix} \tag{11}$$

The equation (1) can be rewritten for real valued 8×4562325 received signal Y_{real} as:

$$Y_{real} = \begin{bmatrix} \Re(Y) \\ \Im(Y) \end{bmatrix} = \begin{bmatrix} \Re(H) & -\Im(H) \\ \Im(H) & \Re(H) \end{bmatrix} \begin{bmatrix} \Re(X) \\ \Im(X) \end{bmatrix} + \begin{bmatrix} \Re(N) \\ \Im(N) \end{bmatrix} \tag{12}$$

The extended 16×8 channel matrix $\hat{H}$ and the 16×4562325 extended received signal $\hat{Y}$ in terms of 8×8 identity and 8×4562325 null matrices are given by

$$\hat{H} = \begin{bmatrix} H_{real} \\ (\sqrt{\sigma_n^2}) I_{8 \times 8} \end{bmatrix} \tag{13}$$

$$\hat{Y} = \begin{bmatrix} Y_{real} \\ \mathbf{0}_{8 \times 4562325} \end{bmatrix} \tag{14}$$

On sorted QR decomposition of $\hat{H}$, a 8×8 permutation matrix P, 16×8 orthogonal matrix Q and a 8×8 upper triangular matrix R with large condition number are produced. Using a typically chosen scaling parameter of value 0.5 in Lenstrat-Lenstra-Lovasz (LLL) algorithm, three new matrices Q_{LLL}, R_{LLL} with small condition number and 8×8 unimodular matrix T_{LLL} are produced.

The modified form of extended channel matrix $\tilde{H}$ in terms

of unimodular matrix, permutation matrix and extended channel matrix can be written as:

$$\tilde{H} = \hat{H}PT_{LLL} \tag{15}$$

The real valued extended 8×4562325transmitted signal X_TEMP is given by

$$X\_TEMP = PT_{LLL}(\tilde{H}^H\tilde{H})^{-1}\tilde{H}^H\hat{Y} \tag{16}$$

In MATLAB notation using for end loop with specification of 4 iterations and real to complex conversion, the estimated transmitted signal X_LRMMSE can be written as:

for i=1:4

$X\_LRMMSE(i,:) = X\_TEMP(i,:) + sqrt(-1)*X\_TEMP(i+4,:)$ end

In Equation(16), the first through fourth rows are the estimated real components and the real values presented in fifth through eight rows are multiplied by sqrt(-1) to get the estimated imaginary components. In matrix form, we can write

$$X\_LRMMSE = \begin{bmatrix} X\_TEMP(1,:)+sqrt(-1)*X\_TEMP(5,:) \\ X\_TEMP(2,:)+sqrt(-1)*X\_TEMP(6,:) \\ X\_TEMP(3,:)+sqrt(-1)*X\_TEMP(7,:) \\ X\_TEMP(4,:)+sqrt(-1)*X\_TEMP(8,:) \end{bmatrix} \tag{17}$$

However, the detected signal is filtered for salt and pepper noise reduction using 2D median filtering technique**.** In 2-D Median Filtering scheme, a 3×3 neighborhood windowing mask is used for simply sorting all the pixel values within the window and finding the median value and replacing the original pixel value with the median value[5-7].

3. System Description

A video file in mp4 format is downloaded from a website at   https://www.youtube.com/ watch?feature=player_detailpage&v=J5XESDvBdsY#t=3.The total number of video frame is 2910 with a frame rate of 30 RGB frames/sec. The number of video frame used in this present simulation study is 5. The resolution of each video frame is of 480 pixels (width) ×360 pixels (height) with identical 96 dpi in both vertical and horizontal dimension. The selected video frames are processed in a MIMO MCCMA system depicted in Figure 1.The captured color video frames are converted into their respective three Red, Green and Blue components with each component is of 480 pixels ×360 pixels in size.The pixel integer values[0-255] are converted into 8 bits binary form and channel coded and interleaved and digitally modulated using 16QAM. The modulated complex symbols are copied and multiplied with Walsh–Hadamard (WH) orthogonal codes. The orthogonally encoded signals are processed in Spatial multiplexing(SM) Encoding section to produce four independent data streams. Each of four data streams are serial to parallel converted, OFDM modulated, cyclically prefixed and subsequently parallel to serially converted and transmitted. In receiving

section, the transmitted signals are detected and processed for serial to parallel conversion, cyclic prefix removal, and OFDM demodulation, parallel to serial conversion and decoded in Spatial multiplexing (SM) Decoding section to produce data in single channel. The retrieved data are multiplied with Walsh–Hadamard (WH) orthogonal codes and decopied, digitally demodulated, deinterleaved, channel decoded, binary to pixel integer converted and filtered to reconstruct frames for transmitted video frame retrieval [8-10].

4. Result and Discussion

Table 1. Summary of the simulated model parameters.

Parameters	Values
Data Type	Video Signal
Number of frames	5
Digital modulation	16 - QAM
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 Equalization	MMSE, ZF, OSIC and LR-aided MMSE
Orthogonal spreading code	Walsh-Hadamard
Processing gain of Walsh-Hadamard code	8
Antenna configuration	4 × 4

In this section, computer simulations using MATLAB have been performed to evaluate the BER performance of a 4x4 multi antenna supported and implemented 2D median filtering for noise reduction in MC-CDMA wireless communication system based on the parameters presented in Table 1. In Figure 2, the transmitted five video frames and their corresponding impulsive (salt and pepper) noise contaminated versions have been presented. Contamination rate is 5% viz. 8640 pixels out of 172800 pixels are contaminated with impulsive noise for each 480pixels ×360 pixels sized Red, Green and Blue components of an individual video frame. In Figure 3, histograms of captured RGB to Gray converted five video frames are presented. The histograms are indicative of pixel intensity values(0 to 255)and the absence of intensity values in the upper range: 200-255 confirms that the captured 100th video frame is not bright. In other cases except 2000th video frame , pixel intensity values are distributed over the almost whole band of pixel values.The graphical illustrations presented in Figure 4 through Figure 7 show system performance comparison(Bit error rate(BER) vs SNR values) for 1/2- rated Convolutionally encoded MIMO MC CDMA system with various signal detection, noise reduction and 16-QAM digital modulation schemes. In all cases, the impact of MMSE signal detection technique on system performance enhancement is clearly observable at low SNR value area. It is also noticeable in case of all the captured video frames that the simulated system shows identical performance over a

significant part of SNR values. The estimated bit error rate at a typically assumed SNR value of 5 dB with adaptation of MMSE signal detection technique for 100th, 600th, 1100th , 2000th and 2500th video frames are 13.97%, 10.33%,12.19%, 12.36% and 16.01% respectively. The system performance is quite satisfactory for 600th video frame which is found to contain intermediate pixel values around the range: 100-170. In Figure 4 through Figure 8, the system performance improvement at identical signal and noise power(SNR=0dB)

in MMSE signal detection as compared to ZF signal detection are 0.09422 dB,0.09478 dB, 0.10024 dB, 0.06654 dB and 0.07471 dB respectively. In Figure 9, transmitted 1200th video frame, its noise contaminated and retrieved video frames have been presented. The retrieved video frame has a great resemblance with the transmitted video frame and the estimated bit error rate was found to be of 0.066 viz. 3873584 bits are correctly retrieved out of 4147200 bits (480×360×24) for the captured video frame.
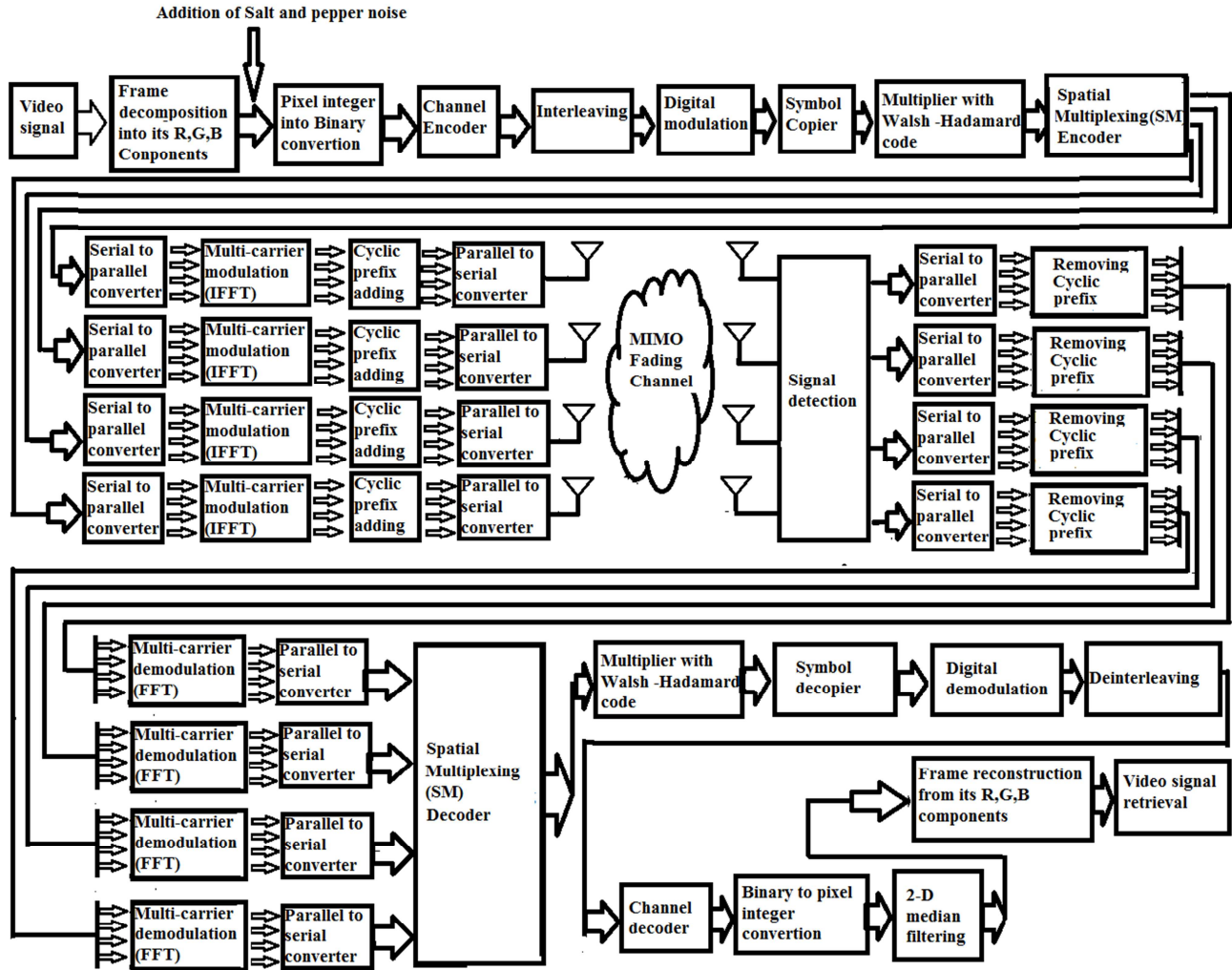
Figure 1. Block diagram of simulated MIMOMCCMA system.
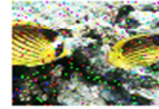
Figure 2. *Transmitted and Salt and Pepper noise contaminated five selected video frames.*
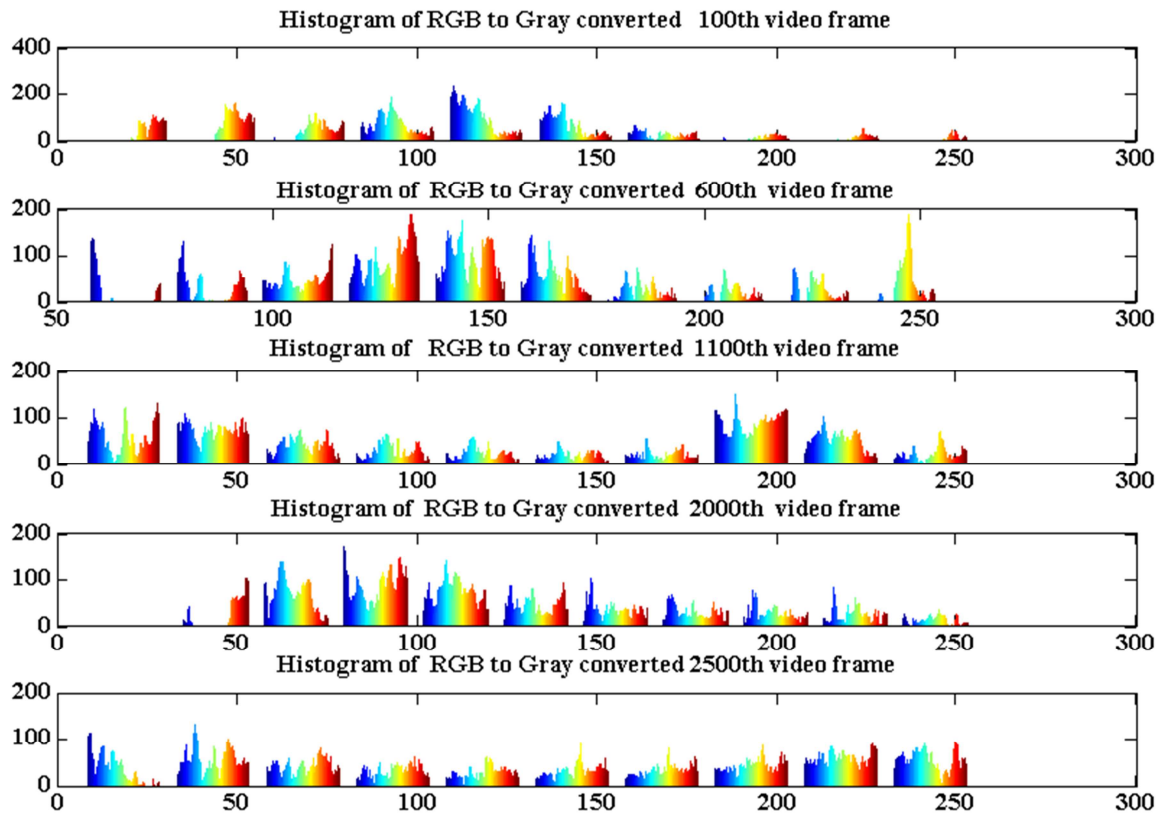
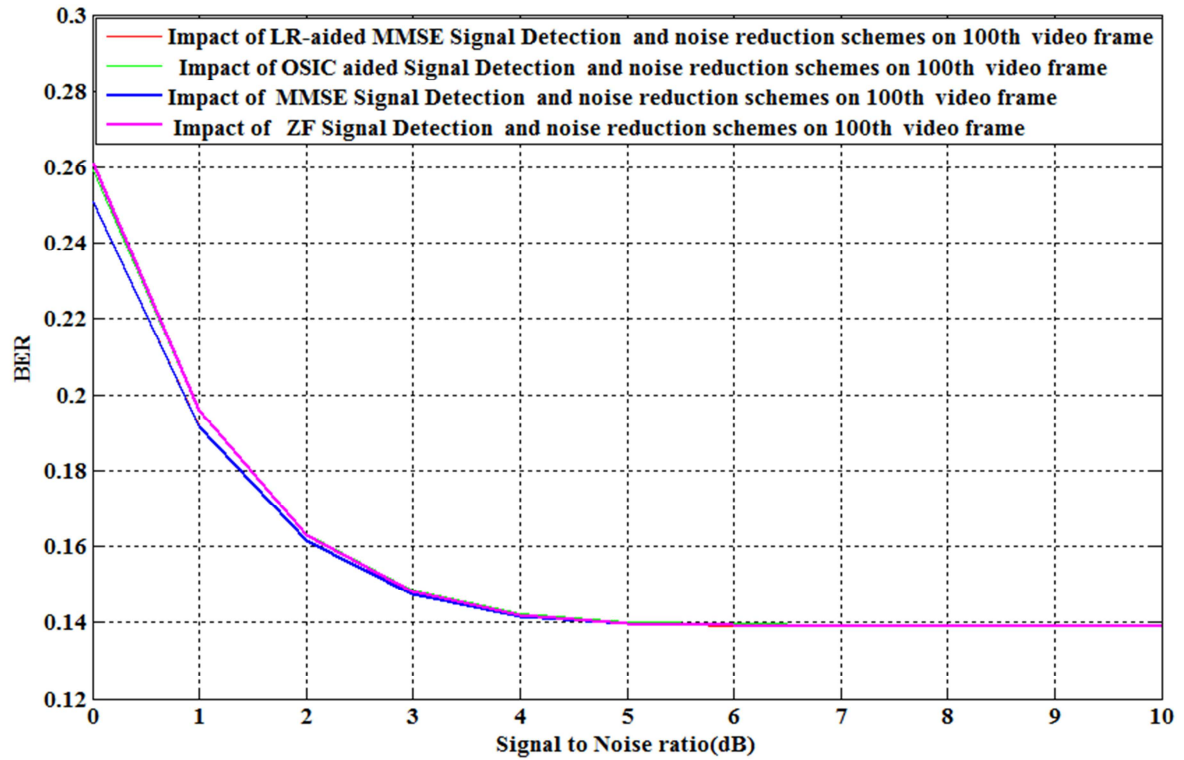**Figure 3.** *Histogram of transmitted RGB to Gray converted five selected video frames.*

Figure 4. BER performance of MIMO MCCDMA system with implementation of various signal detection and 2D median filtering schemes on 100th captured video frame.
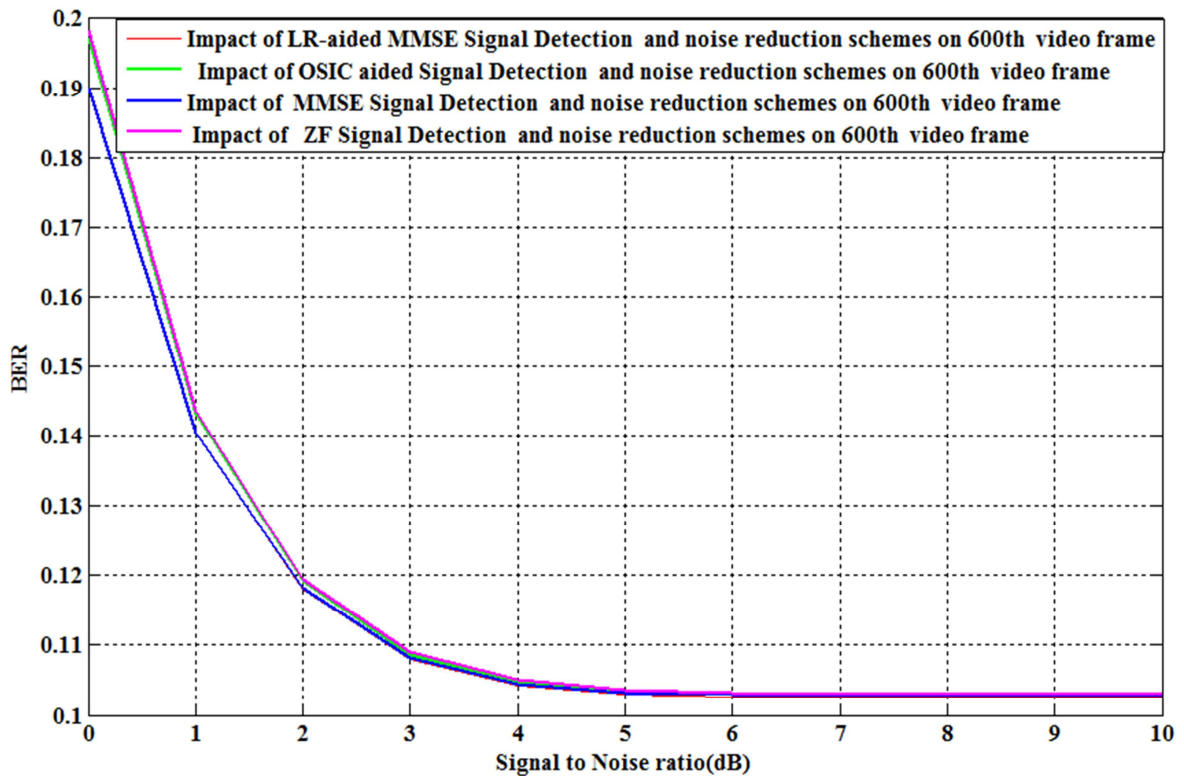

Figure 5. BER performance of MIMO MCCDMA system with implementation of various signal detection and 2D median filtering schemes on 600th captured video frame.
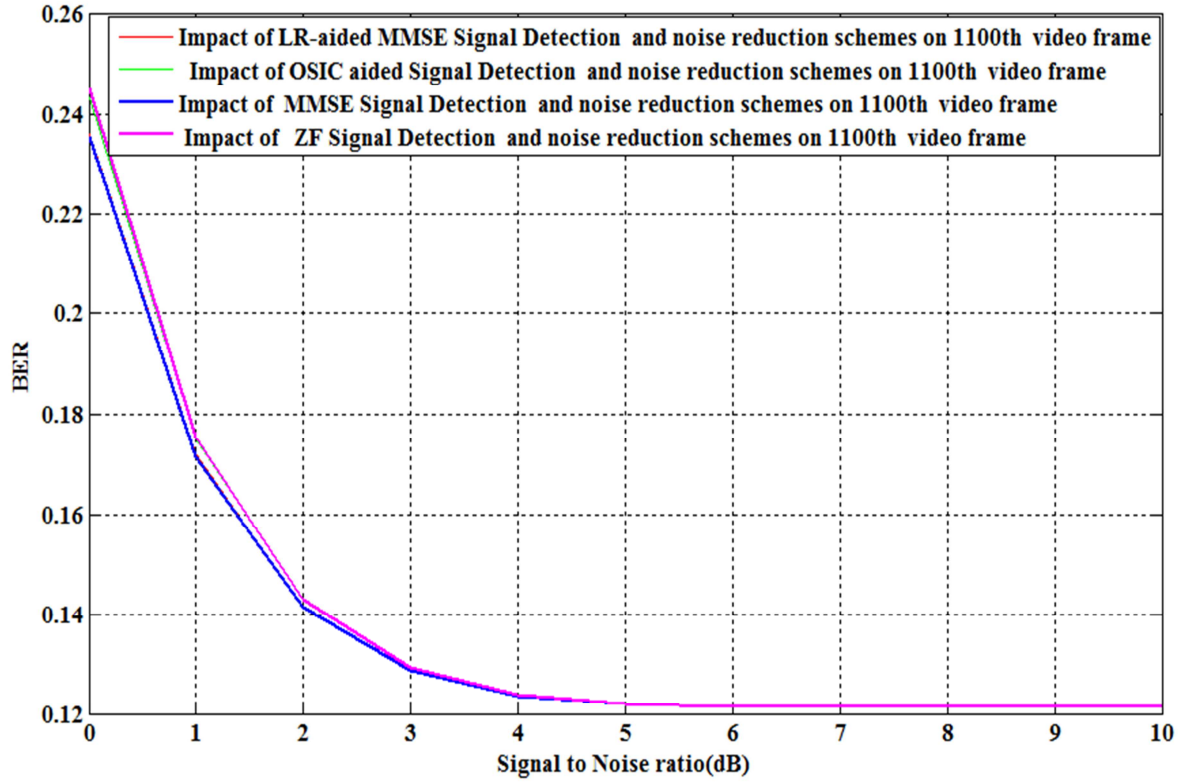
Figure 6. BER performance of MIMO MCCDMA system with implementation of various signal detection and 2D median filtering schemes on 1100th captured video frame.
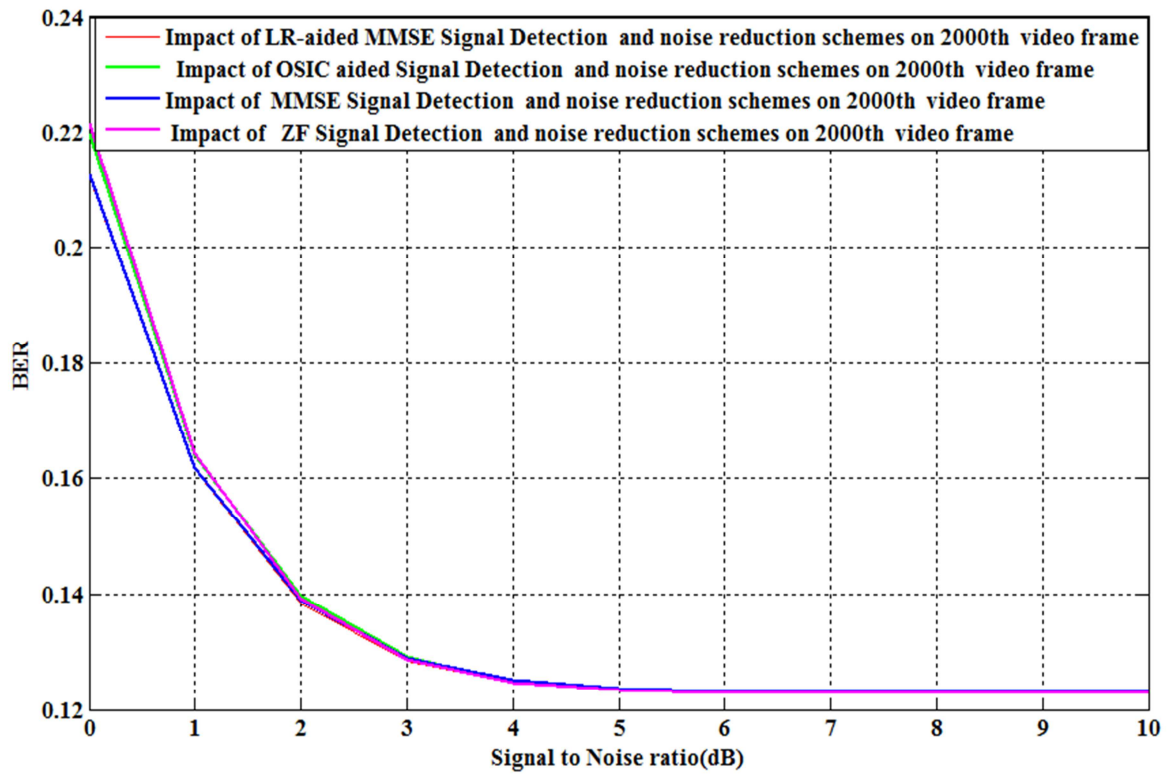

Figure 7. BER performance of MIMO MCCDMA system with implementation of various signal detection and 2D median filtering schemes on 2000th captured video frame.
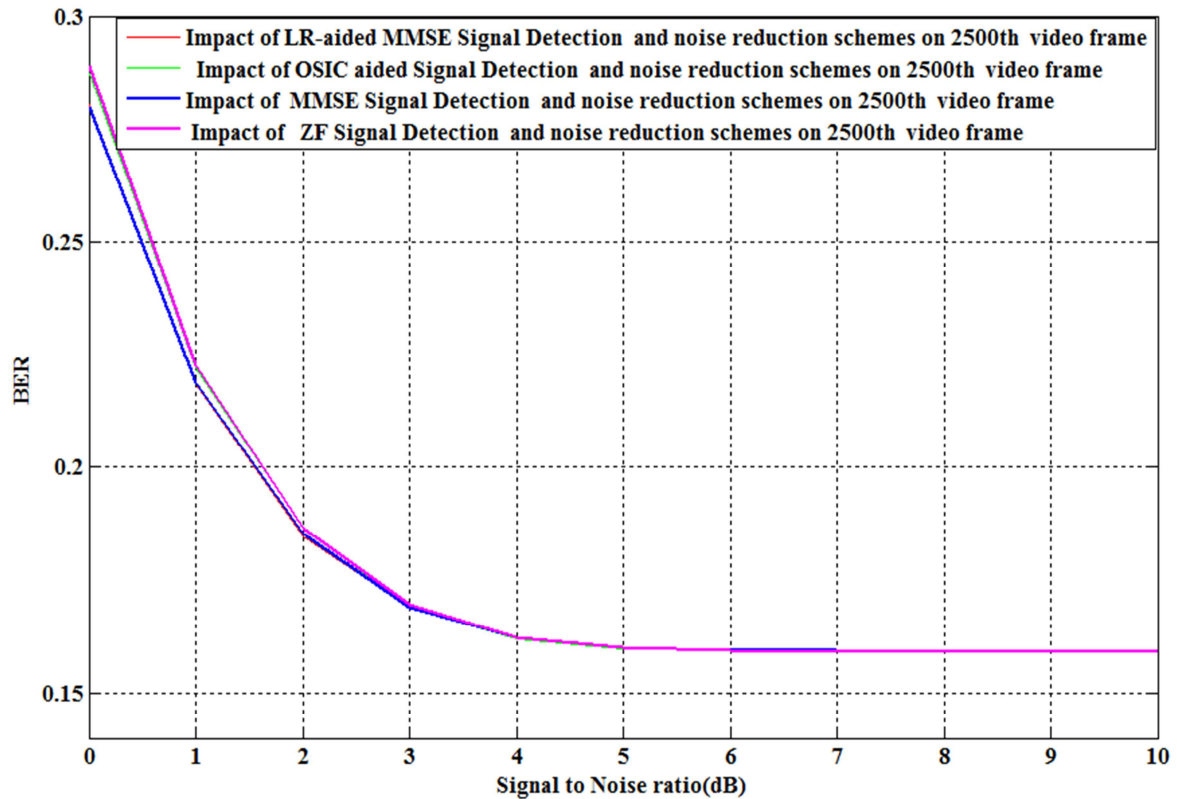
Figure 8. BER performance of MIMO MCCDMA system with implementation of various signal detection and 2D median filtering schemes on 2500th captured video frame.
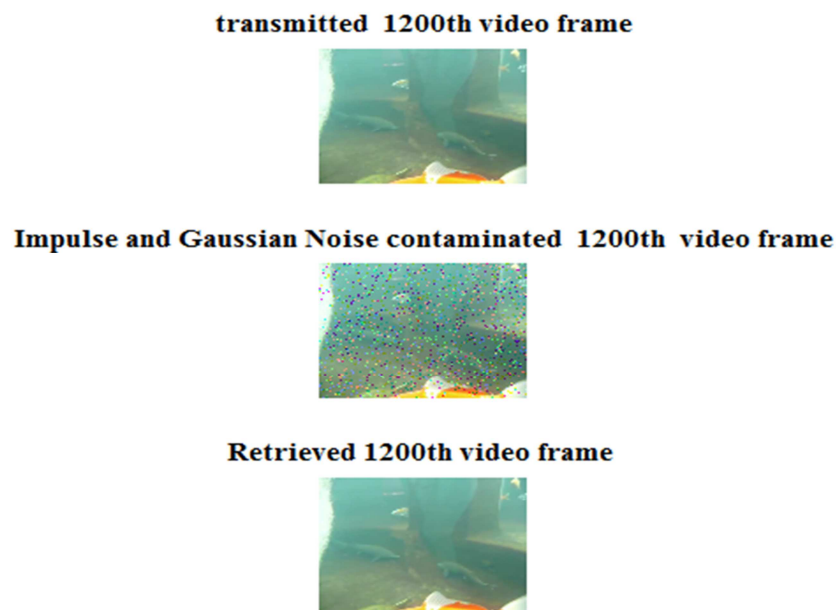

Figure 9. Performance indicator of MMSE signal detection aided MIMO MCCDMA system for a typically assumed captured 1200thvideo frame at SNR value of 5 dB.

5. Conclusions

In this paper, the performance of MIMO MCCDMA wireless communication system has been investigated using various signal detection techniques. The results show that MMSE signal detection scheme is better than other signal detection scheme in retrieving video signal transmitted over impulsive and Gaussian noise contaminated channel. As MC CDMA radio interface technology exploits advantages of both OFDM and CDMA and a great emphasis is being given on video communication, such MCCDMA radio interface technology can be used in 5G compatible dual polarized Massive MIMO antenna system.

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