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Multiview Video Signal Transmission in a Dual Polarized DWT Aided MIMO SC-FDMA Wireless Communication System

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Abstract -In this paper, we made a comprehensive simulative study on multi-view video signal transmission in a dual polarized MIMO single-carrier frequency division multiple access (SC-FDMA) communication system. The system implements various signal processing and signal detection schemes such as Haar based discrete wave transformation(DWT) , two-dimensional nonlinear Median filtering, 1/2-rated Convolutional , Repeat and Accumulate (RA) and BLUE.It is noticeable from such study that the multiview video signal with quite reasonably acceptable video frame quality is retrieved under scenario of implementing 1/2- rated Convolutional channel coding, BLUE and QAM digital modulation schemes.

Index Term - SC-FDMA, dual polarized antennas, DWT, Signal to noise ratio, 2-D nonlinear Median filtering, BLUE

1. Introduction

Three-dimensional (3D) video is an emerging technology and with the technological development in multimedia, various 3D video systems such as stereoscopic 3D (S3D) video, multi-view video (MVV), video-plus-depth, multi-view video-plus-depth (MVD) and layered depth video (LDV) have been known. In Multiview Video (MVV) data acquisition, multi-camera arrays are used to capture the same scene from varying viewpoints. The MVV is characterized by significant inter-view statistical redundancies. The views in MVV can be independently encoded (i.e., simulcast), or jointly encoded by taking advantage of the correlations existing amongst the views. The MVV is especially suited for emerging auto-stereoscopic displays, which require a large number of views with preservation of the full resolution of the video sequence. The major shortcoming of the representation is that, even when using an efficient coding scheme such as MVC, the bit rate essentially grows linearly with the number of encoded views **[1,2].** In 2014, Kodera and et.al., focused on the acquisition of multi-view video with exploitation of multiple mobile cameras and wireless networks. In existing multi-view video acquisition, multi-camera arrays are mutually connected by wires which imposes the limitations of places and objects. However, in such multi-view video data streaming capturing with mobile cameras a reduction in video traffic is achieved maintaining high video quality for communication between mobile cameras and an access point**[3].** Several cellular technologies have surfaced over the past some time with commercial deployment of the long term evolution (LTE) and its successor LTE-advanced (LTE-A) networks in different regions of the world. The LTE-A networks use single-carrier frequency division multiple access (SC-FDMA) for uplink transmissions. In comparison to OFDMA, the SC-FDMA significantly reduces the envelope fluctuations in the transmitted waveform. The SC-FDMA signals have inherently lower peak-to-average power ratio (PAPR) than the OFDMA signals.**[4].** Millimeter wave (mmWave) multiple-input multiple output (MIMO) wireless communication systems are being considered as Fifth generation wireless systems to provide the throughput enhancements needed to meet up the expected demands for mobile data . The dual-polarized antenna systems are expected to be incorporated with mmWave systems **[5].**In 2012, Umaria and et. al., made computer simulation study on performance assessment of both FFT based OFDM system and DWT based OFDM system using different wavelet families and found that the DWT based OFDM system is better than FFT based OFDM system with regards to the bit error rate (BER) performance**[6].** The present study represents SC FDMA system performance on multiview video signal transmission under implementation of dual polarization antenna configuration, Haar based discrete wave transformation (DWT) schemes.

2. Signal Processing techniques

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In our present study, we assume that the captured video is pre processed through various signal processing schemes

A brief overview of these schemes is given below:

2.1 Haar Wavelet Transform

Wavelet decomposition can be demonstrated simply through considering a process of decomposing a typically assumed discrete signal X(z) into coarse approximation a(m) and detail d(m) components using four sets of wavelet filters H_0, H_1, G_0, and G_1. An important property of the wavelet transform is the perfect reconstruction which is the process of rebuilding a decomposed signal into its original transmitted form without deterioration. In Haar wavelet transform, the discrete signal X(z) is decomposed into two components of half the length of original signal. At each decomposition level, the high-pass filter produces the detail component and the low pass filter produces the coarse approximation component. The filtering and decimation process continues until the desired decomposition level is reached. The maximum number of levels depends on the length of the signal. In Haar wavelet transform, the polynomial, P(z) is given by,

$$P(z) = \frac{1}{2}(z+2+z^{-1}) = \frac{1}{2}(z+1)(1+z^{-1}) = G_0(z)\,H_0(z) \quad (1)$$

the filter $H_0(z)$ and $G_0(z)$ are estimated using the following relation:

$$H_0(z) = \frac{1}{2}(1+z^{-1}) \quad (2)$$

$$G_0(z) = (z+1) \quad (3)$$

The other two filters $H_1(z)$ and $G_1(z)$ are estimated using the following relation:

$$G_1(z) = zH_0(-z) = \frac{1}{2}z(1-z^{-1}) = \frac{1}{2}(z-1) \quad (4)$$

$$H_1(z) = z^{-1}G_0(-z) = z^{-1}(-z+1) = (z^{-1}-1) \quad (5)$$

The approximation and detail coefficients can be expressed as follows **[7]**:

$$a(m) = \sum_{k=-\infty}^{\infty} x(k)H_0(2m - k) \quad (6)$$

$$d(m) = \sum_{k=-\infty}^{\infty} x(k)H_1(2m - k) \quad (7)$$

where, m ranges from 1,2,3……. 32 as the total number of samples used in a single block wise processing is 64.

2.2 Dual Polarized MIMO Channel

A 4× 4 dual polarized MIMO channel $\mathbf{H}_\chi \in \mathbb{C}^{4\times4}$ is parameterized by a single parameter and can be modeled as:

$$\mathbf{H}_\chi = \mathbf{X} \odot \mathbf{H}_w \quad (8)$$

where, $\mathbf{H}_w \in \mathbb{C}^{4\times4}$ denotes a single polarized MIMO channel having i.i.d. entries with $\mathcal{C}(0, 1)$,$\mathbf{X} \in \mathbb{C}^{4\times4}$is a matrix describing the power imbalance between the orthogonal polarizations. It is modeled as:

$$X = \begin{bmatrix} 1 & \sqrt{\chi} \\ \sqrt{\chi} & 1 \end{bmatrix} \otimes 1_{2\times2} \quad (9)$$

The parameter $0 \le \chi \le 1$ stands for the inverse of the cross-polar discrimination (XPD), where $1 \le XPD \le \infty$. The XPD refers to the physical ability of the antennas to distinguish the orthogonal polarization. In Equation 1, $\odot$is theHadamard product of $\mathbf{X}$ and $\mathbf{H}_w$. Equation 8 can be written in s a block matrix representation as: **[8].**

$$H_\chi = \begin{bmatrix} H_{w,11} & \sqrt{\chi}H_{w,12} \\ \sqrt{\chi}H_{w,21} & H_{w,22} \end{bmatrix} \quad (10)$$

2.3 Best Linear Unbiased Estimation (BLUE)

In BLUE based signal detection scheme, it is assumed that the channel matrix $\mathbf{H}_\chi$is deterministic and the covariance matrix R_{ee} (=E{NN^T}) of the contaminated noise N is positive definite and its inversion matrix R^{-1}_{ee} is known or can be estimated. The noise covariance matrix R_{ee} is of dimension 4 × 4. The estimated transmitted signal X_{BLUE} using such scheme can be written in terms of Y(Received signal),$\mathbf{H}\chi$and R_{ee}, as **[9]**:

$$X_{BLUE} = (\mathbf{H}_\chi^T R^{-1}_{ee}\,\mathbf{H}_\chi)^{-1}\mathbf{H}_\chi^T R^{-1}_{ee} Y \quad (11)$$

2.4 2-D Median Filtering

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The 2-D Median Filter is a non- linear filter or order-static filter used for salt and pepper noise reduction. In such scheme, 3×3 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**[10]**

2.5 Repeat and Accumulate (RA)

In RA, a powerful modern error-correcting channel coding scheme, the extracted binary bits from the colorimage 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**[11].**

2.6 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 with½ 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**[12]**

$G1= x^0+x^2+ x^3+x^5+ x^6=1\ 0\ 1\ \ 1\ 0\ \ 1\ \ 1 =133$
$G2= x^0+x^1+ x^2+x^3+ x^6=1\ 1\ 1\ \ 1\ 0\ \ 0\ \ 1 =171$(12)

3. System Description

The dual polarized DWT aided MIMO SC FDMA wireless communication system is depicted in Figure 1.

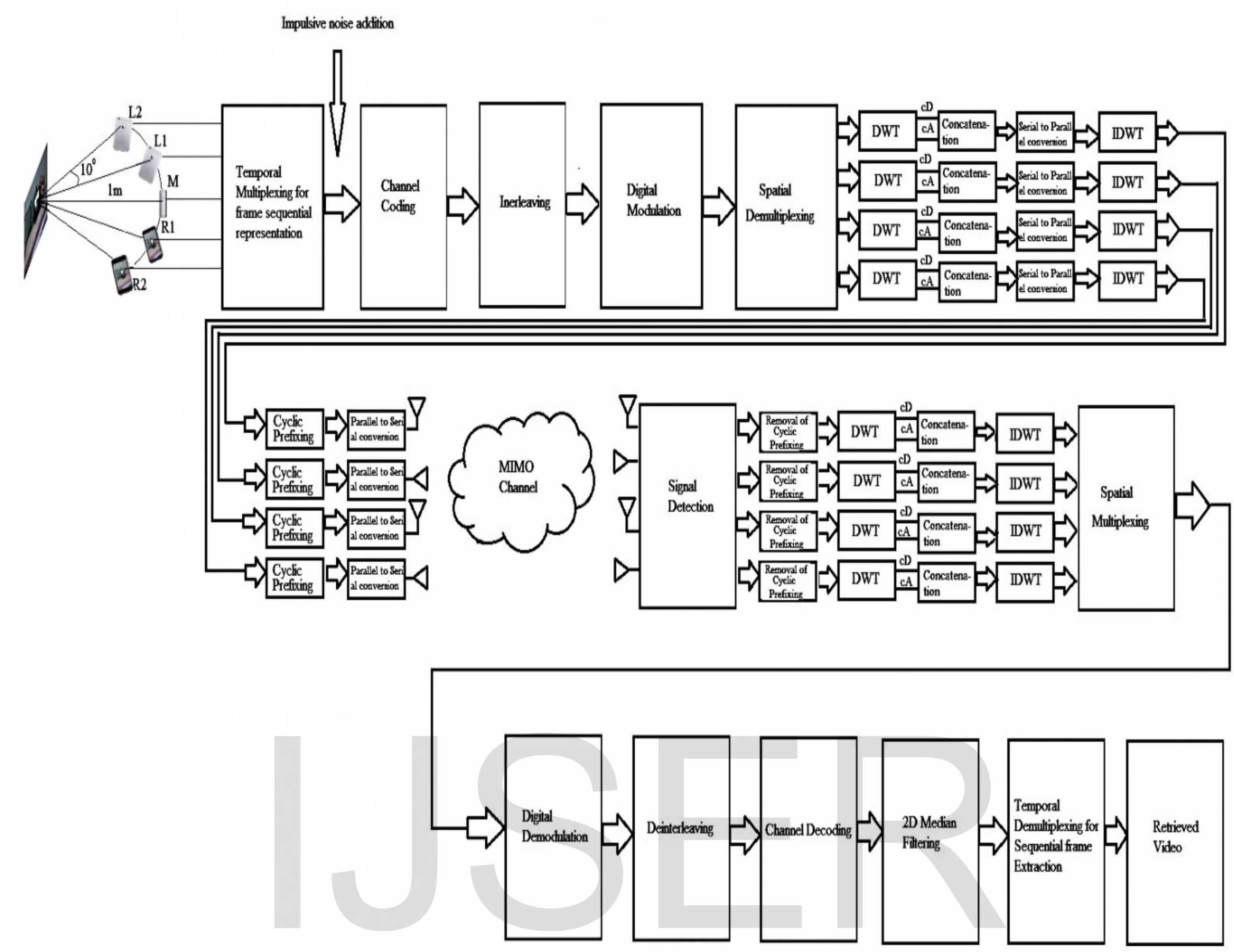

Figure 1: Simplified Block diagram of Multiview video signal transmission in a dual polarized DWT aided MIMO SC-FDMA wireless communication system

The videos of a fixed object are captured by Sony Xperia Z smart phone from five locations(two left:L1,L2,one middle :M, and two right: R1 and R2) situated in a arc path maintaining a distance of 1 meter from the object. The angular displacement between two consecutive locations is 10 degree. The time duration of each captured video is 10 second with a frame rate of 30 RGB frames/sec. The video frames are temporally multiplexed for frame sequential representation. The number of multiplexedvideo frames used in this present simulation study is 10. The resolution of each video frame is of 1080 pixels (height) ×1920 pixels(width) and it is converted into its respective three Red, Green and Blue components. The pixel integer values **[0-255]** of each color components are contaminated with impulsive noise, undergone into integer to binary conversion, channel encoded, interleaved and eventually digitally modulated with QAM .The complex digitally modulated symbols are spatially demultiplexed to produce four data stream. Each data stream is rearranged into 194400 blocks with each block consisting of 64 symbols. A 64 point discrete wavelet transformation(DWT) algorithm is applied to each block to produce details and approximate coefficients. These coefficients are concatenated block wise , spatially mapped into a block of 64*194400 data symbols, serial to parallel converted with 2048 parallel data symbols and are transformed with inverse discrete wavelet transformation(IDWT), cyclically prefixed ,parallel to serially converted and transmitted from four dual polarized antennas. In receiving end, transmitted signals are detected using various signal detection techniques. The detected signals are processed with subsequent cyclic prefix removing, 64 point DWT transformed with its output coefficients

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concatenation, inverse discrete wavelet transformed(IDWT), spatially multiplexed , digitally demodulated , deinterleaved, channel decoded, filtered with 2D median filtering, temporal demultiplexed to recover transmitted video frames.

4. Result and Discussion

We have conducted computer simulations using MATLAB **R2014a** to evaluate the quality of the multiview video signal transmitted in a dual polarized DWT aided MIMO SC-FDMA wireless communication system based on the parameters given in Table 1.

Table 1: Summary of the simulated model parameters

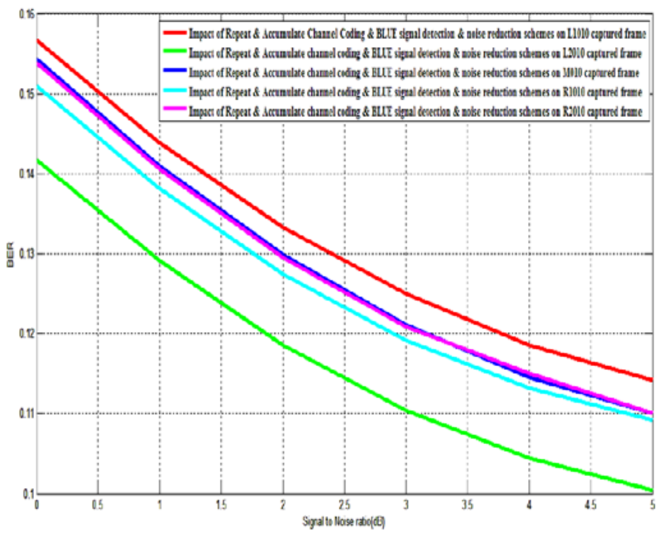
No. of video Capturing location	5
No. of video frames considered at each location	2
value of parameter χ used in dual polarized MIMO channel	0.85
Antenna Configuration	4 × 4
No of video frames/second	30
Video frame size	1080 pixels(height) × 1920 pixels(width)
Digital Modulation	QAM
Fading channel	Rayleigh Fading
Noise type	Gaussian and Impulsive(Salt and pepper)
pixel contamination with Impulsive noise	5%
Channel Coding	Repeat & Accumulate and Half-Rated Convolutional Coding
Signal to noise ratio (SNR)	1 to 5 dB
Noise reduction image Filter	2D Median filtering

SNR value of 5 dB the estimated BER was found to be of 0.0959 viz. 449949000 bits are correctly retrieved.

Figure 2: Captured video frames (10th and 250th)at each of five locations L2, L1, M, R1 and R

In Figure 2, a total number of 10 video frames(10th and 250th at each of five locations L2, L1, M, R1 and R2) have been presented. In Figure 3, Salt and pepper noise contaminated video frames are shown. Each color video frame consists of Red, Green and Blue components with 1080 pixels × 1920 pixels size and its 5% viz. **103680** pixels out of **2073600** pixels are contaminated with impulsive noise. The graphical illustrations presented in Figure 4 through Figure 7 show system performance comparison in terms of Bit error rate (BER) vs SNR values. In all cases, the system performance is well defined under scenario of implementing BLUE signal detection, channel coding(½-rated Convolutional/ Repeat and Accumulate),QAM digital modulation and 2-D median image filtering schemes. it is noticeable in Figure 4 and 5 that the estimated BER values in a typically assumed SNR value of 3dB for 10th frame in each of the five positions are 0.1115, 0.0978, 0.1074, 0.1068, 0.1073 and 0.1250, 0.1104, 0.1211, 0.1192, 0.1209 respectively yielding system performance improvement of 0.5 dB, 0.7dB, 0.52dB, 0.48dB and 0.52dB in ½-rated Convolutional channel coding as compared to Repeat and Accumulate channel coding. Similarly, it is observable from Figure 6 and 7 that the estimated BER values in a typically assumed SNR value of 1dB for 250th frame in each of the five positions are 0.1345, 0.1314, 0.1386, 0.1160, 0.1350 and 0.1553, 0.1512, 0.1583, 0.1367, 0.1556 respectively yielding system performance improvement of 0.62 dB, 0.61dB, 0.58dB, 0.71dB and 0.62dB in ½-rated Convolutional channel coding as compared to Repeat and Accumulate channel coding. .In Figure 8,

The transmitted 10 th frame in L2 position , its noise contaminated and retrieved forms have been presented. The retrieved video frame gets a great resemblance with the transmitted video frames and at a typically assumed



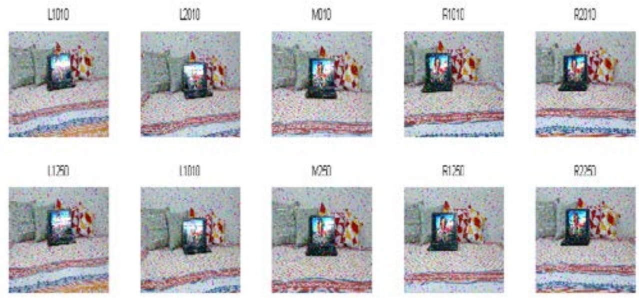


Figure 3: Salt and pepper noise contaminated video frames (10th and 250th)at each of five locations L2, L1, M, R1 and R2

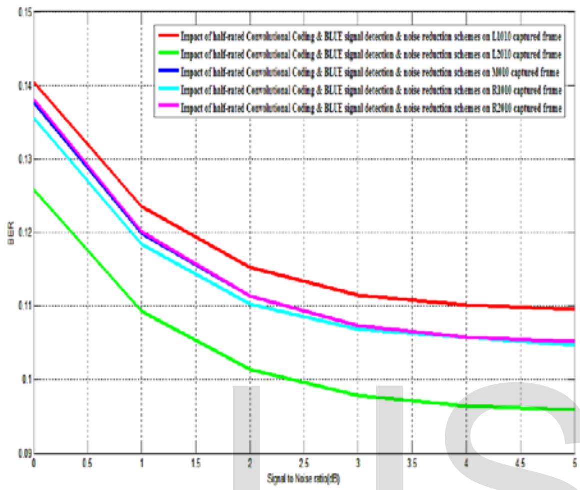


Figure 4: BER performance of dual polarized DWT aided MIMO SC-FDMA wireless communication system with implementation of 2D median filtering, ½-rated Convolutional channel coding, BLUE signal detection and QAM digital modulation schemes on 10th frame of each of five locations: L2, L1, M, R1 and R2

Figure 5: BER performance of dual polarized DWT aided MIMO SC-FDMA wireless communication system with implementation of 2D median filtering, Repeat and Accumulate channel coding, BLUE signal detection and QAM digital modulation schemes on 10th frame of each of five locations: L2, L1, M, R1 and R2

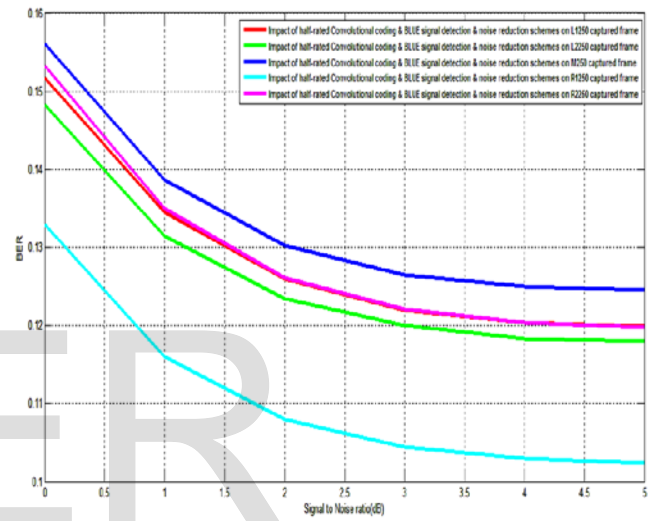


Figure 6: BER performance of dual polarized DWT aided MIMO SC-FDMA wireless communication system with implementation of 2D median filtering, ½-rated Convolutional channel coding, BLUE signal detection and QAM digital modulation schemes on 250th frame of each of five locations: L2, L1, M, R1 and R2

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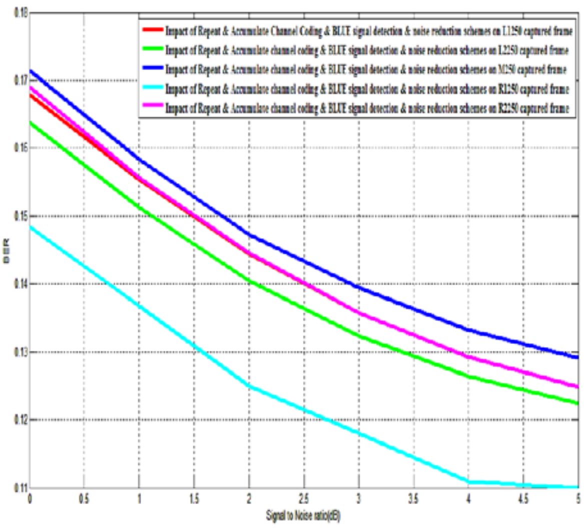

Figure 7: BER performance of dual polarized DWT aided MIMO SC-FDMA wireless communication system with implementation of 2D median filtering, Repeat and Accumulate channel coding, BLUE signal detection and QAM digital modulation schemes on 250th frame of each of five locations: L2, L1, M, R1 and R2

Figure 8: Performance indicator of dual polarized DWT aided MIMO SC-FDMA wireless communication system for a typically assumed 10th video frame captured with smartphone located at the L2 position.

5. Conclusions

In this paper, the performance of dual polarized DWT aided MIMO SC FDMA wireless communication system has been investigated on multiview video signal transmission using QAM digital modulation, BLUE signal detection and various FEC channel encoded schemes .The results show that the implementation of BLUE signal detection with ½-rated Convolutional channel coding and QAM digital modulation schemes ratifies the robustness of system performance in retrieving video frames transmitted over impulsive noise contaminated and Rayleigh fading channels. Such system can be utilized for other form of data transmission in hostile fading channels where induced noise with its power is comparable with the power of transmitted signal .

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