Performance Assessment Of Dual Polarized Dct-Ifdma Sc-Fdma 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 observe critically the performance of DCT-IFDMA aided SC-FDMA wireless communication system on video signal transmission. The 4×4 dual polarized multi antenna supported system utilizes various useful digital signal processing schemes such as BLUE, Q-less QR decomposition, 2D Median Filtering, Repeat and Accumulate (RA). It is observable from MATLAB based simulative study that the system shows quite acceptable and satisfactory performance in retrieving transmitted video signal under scenario of flat fading channel with impulsive noise contamination environment for the specific case of implementing BLUE signal detection, QAM digital modulation and Repeat and Accumulate channel coding scheme.**

Keywords—DCT, IFDMA, Dual Polarized, SC-FDMA, Signal to noise ratio (SNR), BLUE and Q-less QR decomposition

I. Introduction

With rapid growth of mobile data traffic, it is being observed a massive deployment of cellular mobile networks in different parts of the world. In perspective of deployed mobile networks, it has been known that the Single-Carrier Frequency Division Multiple Access (SC-FDMA) system is attracting much attention as an efficient alternative to the Orthogonal Division Multiple Access (OFDMA) system in the uplink communications. 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 . 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**.** The SC-FDMA can be regarded as a DFT-spread OFDMA, where time domain data symbols are transformed to frequency domain by the DFT before going through the OFDMA modulation. In the SC-FDMA systems, a set of orthogonal subcarriers is allocated for each user as in the OFDMA system **[1,2].**

The SC-FDMA system uses different sub channels(subsets of subcarriers) to transmit the information symbols in parallel with each other, various subcarriers assigning schemes such as IFDMA(Interleaved FDMA), DFDMA(Distributed FDMA) and LFDMA (Localized FDMA) are used in SC-FDMA systems. The SC-FDMA systems with IFDMA and LFDMA have better PAPR performance than OFDMA systems.**[3]**

In this present study, it has been tried to observe the performance of Dual Polarized DCT-IFDMA aided SC-FDMA wireless communication system on video signal transmission.

II. Signal Processing Techniques

In our present study various signal processing schemes have been used. A brief overview of these schemes is given below:

A. Dual Polarized MIMO Channel

We assume that the captured video is pre processed through various signal processing schemes prior to transmission through a generated 4× 4 dual polarized MIMO channel. The channel $\mathbf{H}_{\chi} \epsilon \mathbb{C}^{4x4}$ is a dual-polarized MIMO channel parameterized by a single parameter and can be modeled as:

$$\mathbf{H}_{\chi} = \mathbf{X} \odot \mathbf{H}_{w} \quad (1)$$

where, $\mathbf{H}_{w} \epsilon\ \mathbb{C}^{4x4}$ denotes a single polarized MIMO channel having i.i.d. entries with □(0, 1) , $\mathbf{X}\ \epsilon \mathbb{C}^{4x4}$ is a matrix describing the power imbalance between the orthogonal polarizations. It is modeled as:

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

The parameter 0 ≤ χ ≤ 1 stands for the inverse of the cross-polar discrimination (XPD), where 1 ≤XPD≤∞. The XPD refers to the physical ability of the antennas to distinguish the orthogonal polarization. In Equation 1, ⊙ is the Hadamard product of **X** and $\mathbf{H}_{w}$. Equation 1 can be written in a block matrix representation as: **[4].**

$$H_{\chi} = \begin{bmatrix} H_{w,11} & \sqrt{\chi}\, H_{w,12} \\ \sqrt{\chi}\, H_{w,21} & H_{w,22} \end{bmatrix} \quad (3)$$

B. 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**[5]**:

$$X_{BLUE} = (\mathbf{H}_{\chi}^{T} R^{-1}_{ee} \mathbf{H}_{\chi})^{-1} \mathbf{H}_{\chi}^{T} R^{-1}_{ee} Y \quad (4)$$

C. Q-Less QR Decomposition

With Q-less QR Decomposition scheme, the

detected signal X_{QR} can be found based on the least squares approximate solution as:

$$X_{QR} = R \backslash (R^{H} \backslash (\mathbf{H}_{\chi}^{H} * Y))$$

$$R = Y - \mathbf{H}_{\chi} * X_{QR} \quad (5)$$

$$e = R \backslash (R^{H} \backslash (\mathbf{H}_{\chi}^{H} * R))$$

$$X_{QR} = X_{QR} + e$$

where , Y is the received signal, R is an

upper triangular matrix obtained from QR decomposition of channel matrix $\mathbf{H}_{\chi}$**[6,7]**.

D. Repeat and Accumulate (RA)

In RA, a powerful modern error-correcting coding scheme, the extracted binary bits from the color image 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**[8].**

E. 2D Median Filtering

In 2D 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**[9].**

III. System Description

A video file in mp4 format is downloaded from a website at https:// www. youtube. com/watch?v=wE3fmFTtP9g. The total number of video frame is 3712 with a frame rate of 29 RGB frames/sec. The number of video frame used in this present simulation study is 5. The resolution of each video frame is of 640 pixels (width) ×360 pixels(height) with identical 96 dpi in both vertical and horizontal dimension.

The selected video frames are processed in a Dual Polarized DCT-IFDMA SC-FDMA 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 640 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 QAM and QPSK **.**The digitally modulated complex symbols are blocked with each block consisting of 128 symbols. A 128 point discrete cosine transformation (DCT) algorithm is applied to each block. An interleaved subcarrier mapping scheme is applied to each block making the size of each block is of 512 viz. three zeros are inserted between two consecutive symbols. On application of 512 point inverse DCT, a transformed data of size 512× 1728 symbols are produced. On cyclic prefixing, its size is 532× 1728 symbols. The data is multiplexed into 4 streams. The first stream consists of data of 1st column, 5th column, 9th column and so on. The second stream consists of data of 2nd column, 6th column, 10th column and so on. The third stream consists of data of

3rd column, 7th column, 11th column and so on. The fourth stream consists of data of 4th column, 8th column, 12th column and so on. Eventually, the data are transmitted from each of the four dual polarized antennas. In receiving end, transmitted signals are detected using various signal detection techniques. The detected signals are demultiplexed with subsequent cyclic prefix removing, 512 point DCT transformed, subcarrier demapped, 128 point inverse DCT transformed, demodulated, deinterleaved, channel decoded and eventually retrieval of video signal is made**[10,11].**

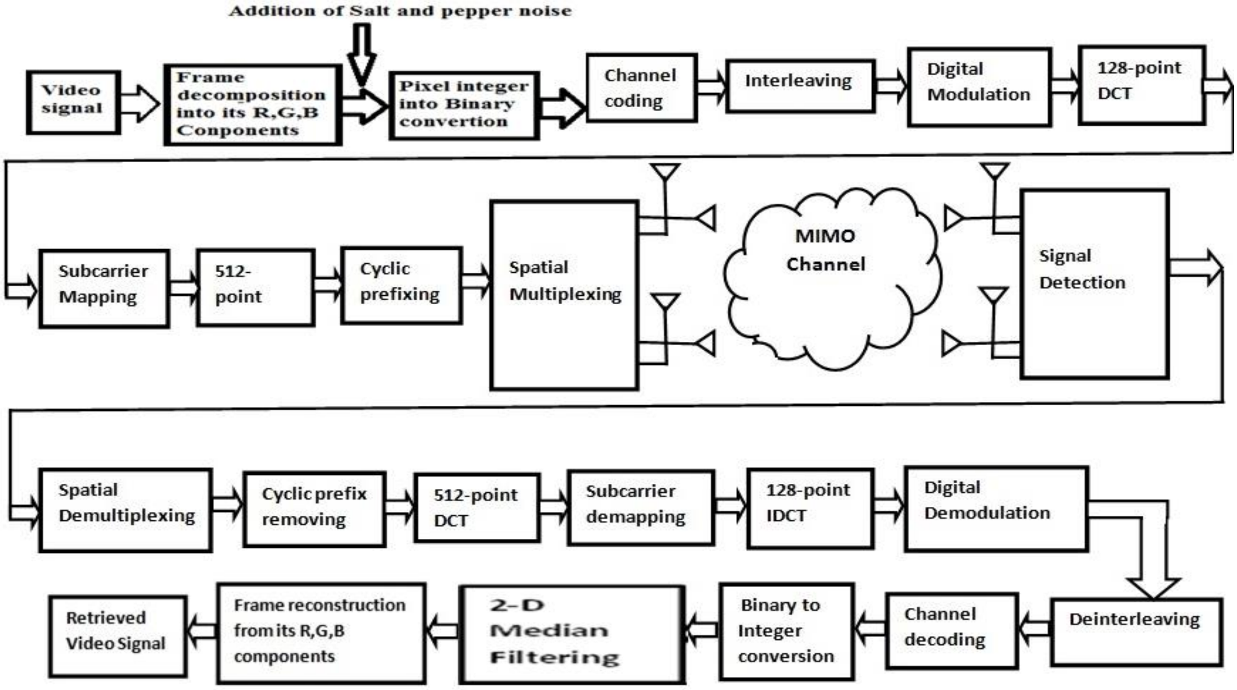

Figure 1: Block diagram of Dual Polarized DCT-IFDMA SC-FDMA Wireless Communication System

IV. Result and Discussion

In this section, computer simulations using MATLAB have been performed to evaluate the BER performance of our presently considered Dual Polarized DCT-IFDMA SC-FDMA 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.

Table 1: Summary of the Simulated Model Parameters

Data type	Video Signal
Number of frames	5
Noise type	Salt and pepper noise
No of interleaved sub carrier mapped complex symbols used in inverse DCT transformation	512
No of complex modulated symbols used in DCT transformation	128
bandwidth spreading factor in IFDMA	4
Cyclic prefixing	20 symbols
Channel Coding	Repeat and Accumulate Code
Antenna configuration with dual polarization	4 × 4
Data Modulation	QPSK and QAM
Signal detection Scheme	BLUE and Q-less QR
Channel	AWGN and Rayleigh fading
Signal to noise ratio, SNR	0 to 5 dB

In impulsive noise contamination, the rate is 5% viz. **11520** pixels out of **230400** pixels are contaminated with impulsive noise for each 640 pixels ×360 pixels sized Red, Green and Blue components of an individual video frame.

The graphical illustrations presented in Figure 3 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 and Q-less QR signal detection, QAM and QPSK digital modulation and Repeat and Accumulate channel coding and 2-D median image filtering schemes. In all cases, the impact of BLUE signal detection technique on system performance enhancement is clearly observable at low SNR value area. It is also noticeable that in case of all the captured video frames, the simulated system shows identical performance over a significant part of SNR values.

In Figure 3 for 46th frame , the estimated BER values are 0.2130 and 0.1095 in a typically assumed SNR value of 1dB for QPSK digital modulation with Q-less QR signal detection as compared to QAM digital modulation with BLUE signal detection which is indicative of a system performance improvement of 2.88 dB. In case of identical signal and noise power(0dB), the estimated BER value under utilization of BLUE, QAM and Repeat and accumulate channel coding is merely 11.07% .In Figure 4 for 91st frame, it is observable that the system shows satisfactory performance in QAM with BLUE signal detection and worst performance in QPSK with Q-less QR. Under such case, the estimated BER values at 1 dB SNR values are found to be of 0.1508 and 0.2542 which ratifies a 2.27 dB system performance improvement.

Figure 2: Transmitted and Salt & Pepper noise contaminated video frames

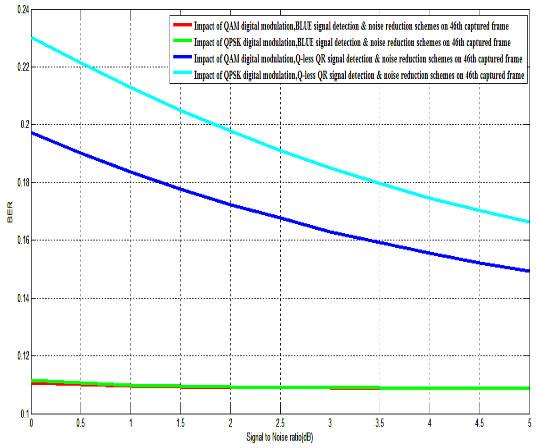

Figure 3: BER performance comparison of dual polarized DCT-IFDMA aided SC-FDMA wireless communication system with implementation of various signal detection, digital modulation and 2D median filtering schemes on 46th captured video frame

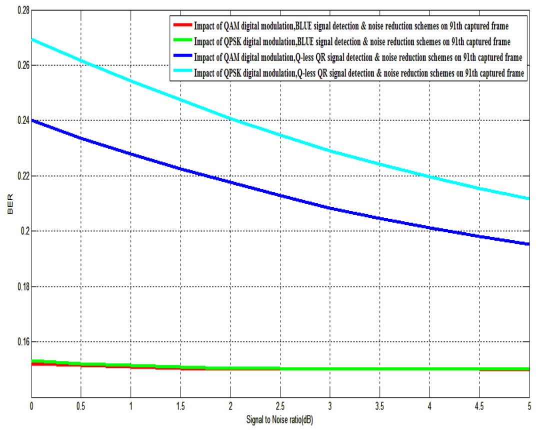

Figure 4: BER performance comparison of dual polarized DCT-IFDMA aided SC-FDMA wireless communication system with implementation of various signal detection, digital modulation and 2D median filtering schemes on 91st captured video frame

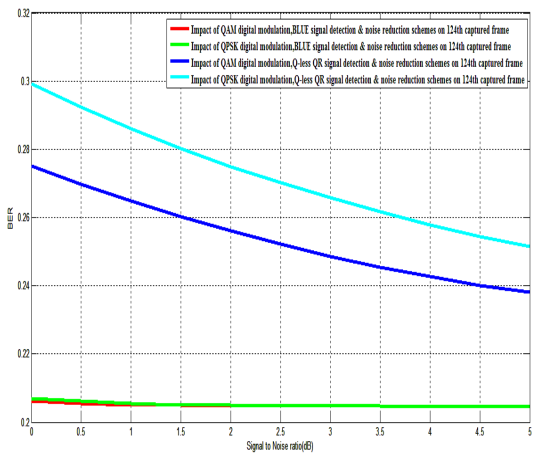

Figure 5: BER performance comparison of dual polarized DCT-IFDMA aided SC-FDMA wireless communication system with implementation of various signal detection, digital modulation and 2D median filtering schemes on 124th captured video frame

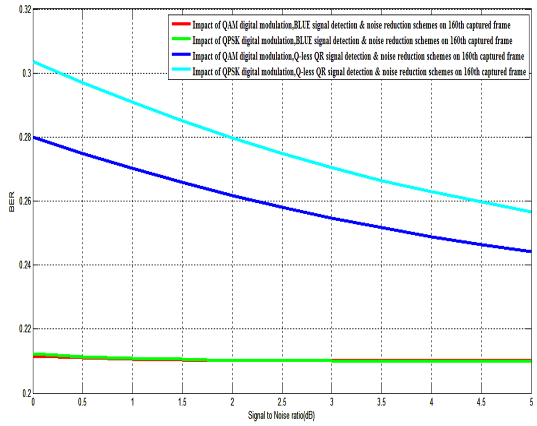

Figure 6: BER performance comparison of dual polarized DCT-IFDMA aided SC-FDMA wireless communication system with implementation of various signal detection, digital modulation and 2D median filtering schemes on 160th captured video frame

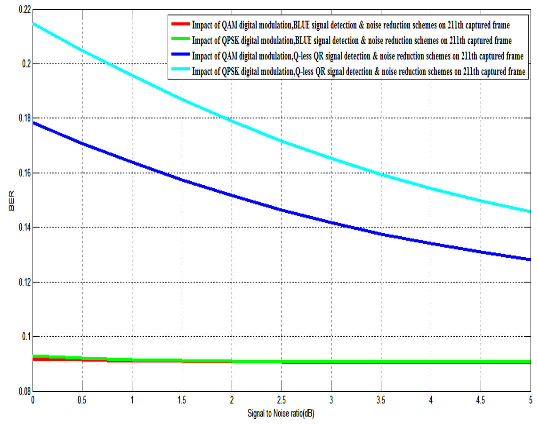

Figure 7: BER performance comparison of dual polarized DCT-IFDMA aided SC-FDMA wireless communication system with implementation of various signal detection, digital modulation and 2D median filtering schemes on 211th captured video frame

In Figure 5 for 124th frame, it shows satisfactory performance in QAM with BLUE signal detection and worst performance in QPSK with Q-less QR signal detection. In such case, the estimated BER values are 0.2051 and 0.2861 for a typically assumed SNR value of 1dB which indicates a system performance improvement of 1.45dB. In Figure 6 for 160th frame, it is noticeable that the system shows satisfactory performance in QAM with BLUE signal detection and worst performance in QPSK with Q-less QR signal detection. The estimated BER values are 0.2106 and 0.2909 for a typically assumed SNR value of 1dB which indicates a system performance improvement of 1.40dB. In Figure 7 for 211th frame, it is noticeable that the system shows satisfactory performance in QAM with BLUE signal detection and worst performance in QPSK with Q-less QR signal detection. The estimated BER values are 0.0910 and 0.1956 for a typically assumed SNR value of 1dB which implies a system performance improvement of 3.32dB. In Figure 8, the transmitted 211th 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 **0.0905** viz**.** 5029364 bits are correctly retrieved out of 5529600 bits(640×360×24) for the captured video frame.

Figure 8: Performance indicator of Dual PolarizedDCT-IFDMA aided SC-FDMA wireless communication system under implementation of Repeat & Accumulate channel coding with BLUE signal detection, QAM digital modulation and 2-D median image filtering for a typically assumed 211th frame at SNR value of 5dB

V. Conclusions

In this paper, the performance of Dual Polarized DCT-IFDMA aided SC-FDMA wireless communication system has been investigated on video signal transmission using various digital modulation, signal detection and FEC channel encoded schemes .The results show that the implementation of BLUE signal detection scheme with Repeat and Accumulate channel coding and QAM digital modulation ratifies the robustness of system performance in retrieving video frames transmitted over salt and pepper 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 power is comparable with signal power.

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