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Secure Color Image Transmission in a Downlink DAS Group Cell Scheme based MIMO OFDMA Wireless Communication System

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Abstract: In this paper, we have made a comprehensive BER simulation study to evaluate the performance of Downlink DAS Group Cell scheme based MIMO OFDMA Wireless Communication System on secure color image transmission. The 4-by-4 multi antenna supported simulated system incorporates various signal detection techniques such as Minimum mean square error (MMSE) , Zero-Forcing (ZF), Zero-Forcing successive interference cancellation(ZF-SIC) Minimum mean square error successive interference cancellation(MMSE-SIC) and digital modulation schemes(QPSK, QAM and 16PSK and 16QAM) and Turbo channel coding for forward error correction. From MATLAB based study, it has been explored that the applicability of MMSE signal detection technique with QAM digital modulation in the presently considered Turbo encoded simulated system is very much effective and robust in retrieving transmitted color image.

Keywords: MIMO, OFDMA, BER, DAS, Group Cell, MMSE, MMSE-SIC, ZF, and ZF-SIC, Data Encryption Standard (DES)

I. INTRODUCTION

In wireless mobile communication sector, it is being observed that the demand in mobile broadband communications is increasing dramatically every year as more and more users are subscribing mobile broadband services with their powerful multimedia capabilities and applications supported smartphones and tablets. A new generation of cellular system appears every 10 years or so, with the latest generation (4G) being introduced in 2011. Following this trend, the 5G cellular system is expected to be standardized and deployed by the early 2020s. The deployment of 5G systems will encounter new challenges in terms of data rate, mobility support and QoE(Quality of experience). In such 5G systems, network densification with utilization of Small-Cell Dominant Heterogeneous Networks (HetNets) would provide higher capacity and increased spectrum efficiency and improve subscriber experience whilst lowering cost-per-bit of transporting data. The network densification to explode the increasing demand of mobile users can be achieved either through multi- antenna systems such as massive MIMO and/or Distributed Antenna Systems (DAS)[1]. The DAS was first introduced to improve the indoor coverage performance of wireless communication systems in 1987.The DAS with multiple remote antennas connected to same Base station (BS) is gaining more attention as an effective means for signal quality enhancement, capacity improvement and spatial diversity. It can also be treated as a form of cooperative communication system in which two or more information sources simultaneously transmit a common message. DAS does not require additional radio resources as remote antennas are typically connected to the BS via dedicated wires such as optical fibers [2]. In 2014, a study on DAS Group Cell scheme aided Downlink Turbo encoded MIMO OFDMA Wireless Communication System has been made on synthetically generated data transmission [3]. The present work is an extended form and emphasizes on the system performance of encrypted color image transmission. A Scenario of Distributed Antenna Systems (DAS) with multiple remote antennas connected to a single Base station (BS) is shown in Fig 1.

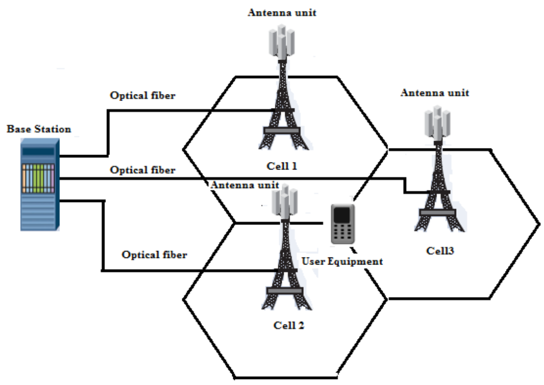

Fig. 1 Scenario of Distributed Antenna Systems (DAS) with multiple remote antennas connected to a single Base Station (BS)

II. MATHEMATICAL MODEL

We assume that a user unit is receiving data from a Base Station with Group Cell based distributed transmitting antennas. The Group Cell is characterized by various adjacent cells that use the same resources to communicate with the user unit. In transmitting section, we consider that the color image is pre-processed, DES encrypted before channel coding, interleaving, digital modulation, frequency domain to time domain signalling, cyclic prefix adding, spatial demultiplexing, encoding prior to transmission through a MIMO fading channel under implementation of MIMO OFDMA radio interface

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technology and data modulation in such case is made with utilization of twelve contiguous subcarriers [4,5].

If $\boldsymbol{H}_1$, $\boldsymbol{H}_2$ and $\boldsymbol{H}_3$ are considered to be the 4 × 4 channel matrices for cell 1 to user unit, cell 2 to user unit and cell 3 to user unit respectively and $\boldsymbol{N}_1$, $\boldsymbol{N}_2$ and $\boldsymbol{N}_3$ are the corresponding zero mean circularly symmetric complex Gaussian noise, $\boldsymbol{X}_S$ is the transmitted signal and PL_{Linear} is the path loss, then the received signal $\boldsymbol{Y}$ can be written as:

$$Y = Y1 + Y2 + Y3 \quad (1)$$

where, $PL_{Linear} = 10^{\wedge}(-\text{path loss in dB}/10)$ and

$$\begin{aligned} Y1 &= H_1X_S + N_1 - PL_{1Linear} \\ Y2 &= H_2X_S + N_2 - PL_{2Linear} \\ Y3 &= H_3X_S + N_3 - PL_{3Linear} \end{aligned} \quad (2)$$

The distance dependent Path-Loss in dB can be written for a carrier frequency of 3.5GHz [2] as:

$$Path\ loss\ in\ dB = 128.1 + 37.6\ log_{10}(R) \quad (3)$$

R is the distance in km from mobile unit to central point of individual cell. After estimating total path loss and assuming $\boldsymbol{H} = H_1 + H_2 + H_3$ and $\boldsymbol{N} = N_1 + N_2 + N_3$ with variance of $\boldsymbol{\sigma_n}^2$, equation (1) can be simplified as:

$$\boldsymbol{Y}_{NEW} = \boldsymbol{H}\boldsymbol{X}_S + \boldsymbol{N} \quad (4)$$

The received signal $\boldsymbol{Y}_{NEW}$ is processed to extract transmitted signal using various signal detection schemes outlined below.

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

$$\boldsymbol{W}_{MMSE} = (\boldsymbol{H}^H\boldsymbol{H} + \sigma_n^2\boldsymbol{I})^{-1}\boldsymbol{H}^H \quad (5)$$

where $(\cdot)^H$ denotes the Hermitian transpose operation and the detected desired signal $\widetilde{\boldsymbol{X}}_{MMSE}$ from the transmitting antenna is given by

$$\widetilde{\boldsymbol{X}}_{MMSE} = \boldsymbol{W}_{MMSE}\boldsymbol{Y}_{NEW} \quad (6)$$

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

$$\boldsymbol{W}_{ZF} = (\boldsymbol{H}^H\boldsymbol{H})^{-1}\boldsymbol{H}^H \quad (7)$$

and the detected desired signal $\widetilde{\boldsymbol{X}}_{ZF}$ from the transmitting antenna is given by[4]

$$\widetilde{\boldsymbol{X}}_{ZF} = \boldsymbol{W}_{ZF}\boldsymbol{Y}_{NEW} \quad (8)$$

In Zero-Forcing Successive Interference Cancellation (ZF-SIC) signal detection scheme, the channel matrix H undergoes QR factorization as

$$H = QR = Q\begin{bmatrix} R_{1,1} & R_{1,2} & R_{1,3} & R_{1,4} \\ 0 & R_{2,2} & R_{2,3} & R_{2,4} \\ 0 & 0 & R_{3,3} & R_{3,4} \\ 0 & 0 & 0 & R_{4,4} \end{bmatrix} \quad (9)$$

where, Q and R are the unitary and upper triangular 4x4 matrices respectively. Here, $R_{p,q}$ denotes the (p, q) th entry of R. Equation (4) can be rewritten on multiplying by Q^H as

$$X = Q^HY_{NEW}$$
$$X = RX_S + Q^HN \quad (10)$$

where, Q^HN is a zero-mean complex Gaussian random vector. Since Q^HN and $\boldsymbol{N}$ have the same statistical properties, Q^HN can be used to denote $\boldsymbol{N}$. We get Equation (10) as

$$X = RX_S + N \quad (11)$$

$$\Downarrow$$

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{bmatrix} = \begin{bmatrix} R_{1,1} & R_{1,2} & R_{1,3} & R_{1,4} \\ 0 & R_{2,2} & R_{2,3} & R_{2,4} \\ 0 & 0 & R_{3,3} & R_{3,4} \\ 0 & 0 & 0 & R_{4,4} \end{bmatrix}\begin{bmatrix} \widetilde{X}_{s1} \\ \widetilde{X}_{s2} \\ \widetilde{X}_{s3} \\ \widetilde{X}_{s4} \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{bmatrix}$$

where, X_k and n_k denote the k-th element of X and N, respectively. The detected desired signal $\widetilde{X}_s$ from the four transmitting antennas can written on neglecting noise term from Equation (11) as

$$\left.\begin{aligned} \widetilde{X}_{s4} &= \frac{X_4}{R_{4,4}} \\ \widetilde{X}_{s3} &= \frac{(X_3 - R_{3,4}\widetilde{X}_{s4})}{R_{3,3}} \\ \widetilde{X}_{s2} &= \frac{(X_2 - R_{2,3}\widetilde{X}_{s3} - R_{2,4}\widetilde{X}_{s4})}{R_{2,2}} \\ \widetilde{X}_{s1} &= \frac{(X_1 - R_{1,2}\widetilde{X}_{s2} - R_{1,3}\widetilde{X}_{s3} - R_{1,4}\widetilde{X}_{s4})}{R_{1,1}} \end{aligned}\right\} \quad (12)$$

In Minimum Mean Square Error Successive Interference Cancellation (MMSE-SIC) scheme, the received signal, channel matrix and noise are extended

$$\begin{aligned} Y_{ex} &= [Y_{NEW}^T\ 0^T] \\ H_{ex} &= \left[H^T \sqrt{\frac{N_0}{E_S}}I\right]^T \\ N_{ex} &= \left[N^T - \sqrt{\frac{N_0}{E_S}}X_S^T\right]^T \end{aligned} \quad (13)$$

where, $\frac{N_0}{E_S}$ is the ratio of average noise power to average signal power (1/SNR). On QR factorization of extended channel matrix, H_{ex}, we get

$$H_{ex} = Q_{ex} \cdot R_{ex} \quad (14)$$

where, Q_{ex} and R_{ex} represent an unitary matrix and an upper triangular matrix respectively. We assume that Y_{NEW}, H, N, Q and R are replaced by Y_{ex}, H_{ex}, N_{ex}, Q_{ex} and R_{ex} respectively and correspondingly, the resulting system takes the following form:

$$x_{ex} = Q_{ex}^H \cdot Y_{ex} = R_{ex} \cdot X_S + Q_{ex}^H \cdot N_{ex} \quad (15)$$

Neglecting noise term in Equation (15) and using matrix inversion scheme, the transmitted signal can be detected [6].

III. RESULTS AND DISCUSSION

In this section, observed BER performance of the 4 x 4 Downlink DAS Group Cell schemes based MIMO OFDMA Wireless Communication System has been analyzed for image transmission with various parameter values presented in Table 1. The simulation results represented in terms of signal to noise ratio (SNR) and bit

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error rate (BER) are done by the developed computer programs written in MATLAB R2014a.

Firstly, it is noticeable that the BER curves depicted in Figure 2 through Figure 6 are clearly indicative of showing distinguishable difference between system performance under various signal detection and digital modulation schemes.

TABLE 1: Summary of the simulated model parameters

Data type	Color image (62 × 70 pixels)
Type of Cooperative technique used	Distributed antennas systems (DAS)
Antenna configuration	4 by 4
No. of adjacent cells in Group	3
Data Modulation	16PSK, 16QAM, BPSK, QAM,QPSK
Receiver signal detection algorithm	MMSE,MMSE-SIC,ZF,ZF-SIC
Cell radius	500 m or 0.5km
Distance-dependent path-loss	L = 128.1+37.6log10(R),R in km
Channel Coding	Turbo Encoding with no. of iteration = 6

In all cases, the simulated system shows worst performance in 16PSK digital modulation.

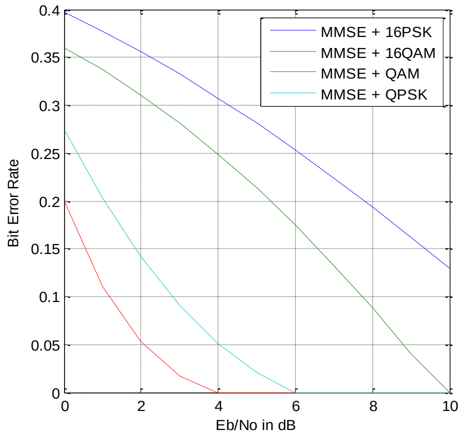

Fig. 2 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA Wireless Communication System with adaptation of MMSE signal detection and various Digital modulation schemes

In Figure 2, it is seen that the Turbo Channel encoded simulated system exhibits better bit error rate (BER) performance with deployment of MMSE signal detection scheme in QAM digital modulation as compared to QPSK, 16-QAM and 16-PSK.

In Figure 3, it is remarkable that at very low SNR values, from 0 to 5 dB, the DAS based Cooperative simulated and Turbo encoded communication system exhibits better bit error rate (BER) performance with deployment of MMSE-SIC signal detection scheme in QPSK digital modulation as compared to 16-PSK, 16-QAM and QAM.

As the SNR increases, from 5 dB to more, the system exhibits better bit error rate (BER) performance with deployment of MMSE-SIC signal detection and other digital modulation schemes.

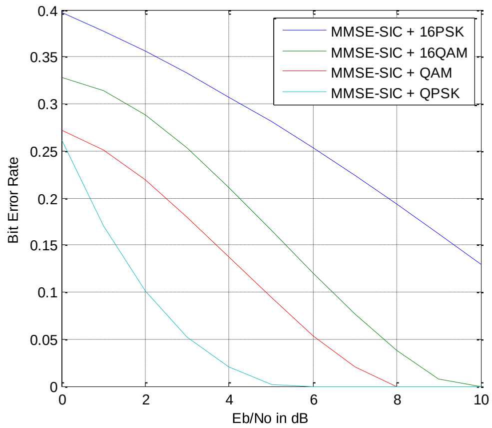

Figure 3: BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of MMSE-SIC signal detection and various Digital modulation schemes

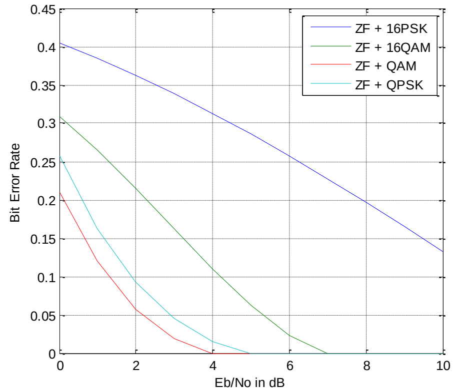

Fig. 4 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of ZF signal detection and various Digital modulation schemes

In Figure 4, it is observable that the Turbo encoded and DAS based Cooperative wireless communication system exhibits better bit error rate (BER) performance with deployment of ZF channel detection scheme in QAM digital modulation as compared to 16-PSK, QAM and 16-QAM. At a typically assumed SNR value of 3 dB, the estimated BER values are 0.0188 and 0.0452 in case of QAM and QPSK which is indicative of a better system performance improvement of 3.80 dB in QAM as compared to QPSK.

In Figure 5, it is noticeable that at very low SNR values from 0 to 5 dB, the Turbo encoded simulated wireless communication system exhibits better bit error rate (BER) performance with deployment of ZF-SIC signal detection scheme in QPSK digital modulation as compared to 16-PSK, QAM and 16-QAM. As the SNR increases, from 5 dB to more, the wireless communication system exhibits almost identical bit error rate (BER) performance with deployment of ZF-SIC signal detection scheme underutilization of QPSK and QAM digital modulation

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schemes. At SNR 4 dB, the estimated BER values are 0.0149 and 0.0284 of QPSK and QAM which implies a system performance improvement of 2.80 dB in QAM as compared to QPSK.

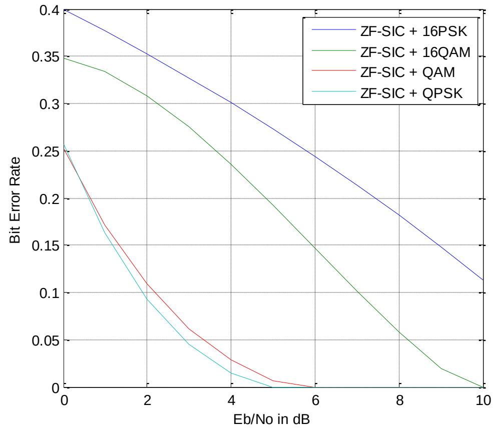

Fig. 5 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of ZF-SIC signal detection and various Digital modulation schemes

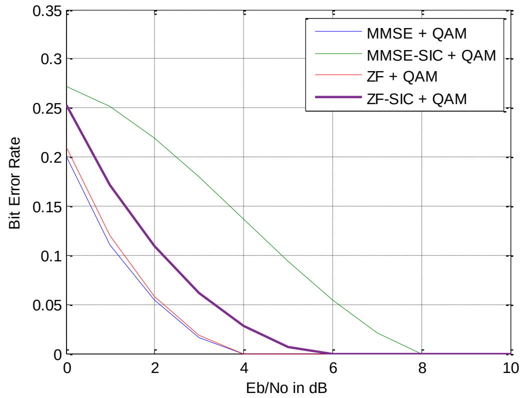

Fig. 6 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of QAM digital modulation and various signal detection schemes

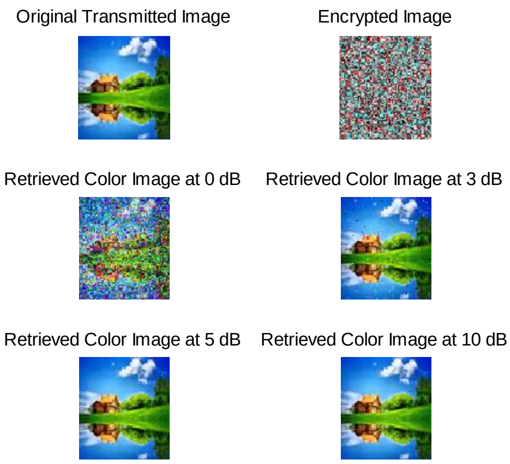

Fig. 7 Transmitted, Encrypted and Retrieved color images at various SNR values in a downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with implementation of MMSE and QAM

In Figure 6, it is found that the DAS based Cooperative wireless communication system under implementation of Turbo channel coding and QAM digital modulation exhibits better bit error rate (BER) performance with deployment of all the four used signal detection schemes(MMSE, MMSE-SIC, ZF and ZF-SIC). At a typically assumed SNR value of 2 dB, the estimated BER values are 0.111 and 0.1199 in case of MMSE and ZF signal detection schemes which ratifies a low system performance improvement of 0.34 dB in MMSE in comparison with ZF.

In Figure 7, it is observed that the encrypted image is highly uncorrelated with the original image. At a comparatively low SNR value of 5 dB, the retrieved image has a significant resemblance with the original transmitted image. On critical observation of BER performance curves presented in Figure 6, it is remarkable that the simulated system shows comparatively better performance in MMSE signal detection technique and also in comparison to other results presented in Figure 3 through Figure 6.

IV. Conclusion

In this paper, the performance of Downlink DAS Group Cell scheme based MIMO OFDMA Wireless Communication System has been investigated using various signal detection, Turbo channel coding and digital modulation techniques. The simulation results are clearly indicative of system performance on secure color image transmission. In the context of system performance, it can be concluded that the implementation of QAM digital modulation technique with deployment of MMSE signal detection ratifies the robustness of system performance in retrieving color image transmitted over AWGN noise contaminated and Rayleigh fading channels for such a Turbo encoded downlink DAS Group Cell scheme based MIMO OFDMA wireless communication system.

References

[1] Jonathan Rodriguez, "Fundamentals of 5G Mobile Networks", John Wiley and Sons Limited, United Kingdom, 2015.
[2] Xiaofeng Tao, Xiaodong Xu, and Qimei Cui, "An Overview of Cooperative Communications", IEEE Communications Magazine, 2012, pp.65-71.
[3] Sohag Sarker and Shaikh Enayet Ullah, "Performance analysis of DAS Group Cell scheme aided downlink Turbo encoded MIMO OFDMA wireless Communication system", International Journal of Scientific and Engineering Research, vol.5, no. 8, 2014, pp.5-9.
[4] Y. S. Cho, J. Kim, W. Y. Yang and C. G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley and Sons (Asia) Pte Ltd, Singapore, 2010.
[5] Goldsmith, Andrea , "Wireless Communications", First Edition, Cambridge University Press, United Kingdom, 2005.
[6] L. Bai and J. Choi, "Low Complexity MIMO Detection", Springer Science and Business Media, LLC, New York, USA, 2012.