

Implementation of Power Efficiency and Error Control Coding in Optical Wireless Systems for Vignetting Correction

Blessy Juliet.J¹, C.J.Profun²

¹M.E. Communication Systems, DMI College of Engineering, Palanchur, Chennai-600 123

²Assistant Professor, Department of ECE, DMI College of Engineering, Palanchur, Chennai-600 123

Abstract— Currently, the demand for high speed wireless multimedia services has grown to a great level. Multiple-Input Multiple-Output (MIMO) Optical Wireless Communication (OWC) can be an excellent supplemental technology to Radio Frequency (RF) links to achieve high transmission rates. One form of MIMO OWC is a pixelated imaging system which transmits information via a series of pixelated image frames. A gradual fall-off in illumination at the edges of a received image will occur due to the Vignetting effect. The Vignetting effect causes attenuation, Inter-Carrier-Interference (ICI) and increased power consumption in the spatial frequency domain. The system performance can be improved by applying a Vignetting Estimation and Equalization scheme. Also an efficient algorithm for reducing the power ratio is implemented. Error Control codes (ECC) is applied for eliminating transmission bit errors. The proposed method shows improvement in the system BER performance.

Keywords— Optical Wireless Communication, MIMO, OFDM, Spatial OFDM, Vignetting, BER, ICI, Attenuation.

I. INTRODUCTION

OPTICAL Wireless Communication (OWC) systems can be used as an alternative to Radio Frequency (RF) systems for short range Indoor Communications. Multiple Input Multiple Output (MIMO) OWC systems have the potential to provide higher data rates than their Single Input Single Output counterparts. One form of MIMO imaging scheme is a pixelated system, where the transmitter transmits a series of pixelated images.

Most pixelated systems use Spatial Orthogonal Frequency Division Multiplexing in the 2-D spatial domain. Spatial Asymmetrically Clipped Optical OFDM (SACO-OFDM) and Spatial DC-biased Optical OFDM (SDCO-OFDM) are two forms of Spatial OFDM that have been developed for MIMO imaging communication. A pixelated system can be impaired by Vignetting which is the gradual illumination fall-off from the centre to the corners of the received images. The vignetting effect introduces Attenuation and ICI in the spatial frequency domain, resulting in bit errors in the Pixelated MIMO Optical wireless systems.

II. PIXELATED OPTICAL SYSTEMS

A Pixelated MIMO Optical Wireless System (OWC) is a type of MIMO Optical Wireless Communication that makes use of the Imaging technique to provide high data rates. The transmitter transmits a series of pixelated images, and a lens along with an array of photodetecting elements reproduces the images at the receiver.

In a pixelated system, the transmitter consists of a 2-D array of optical transmitters which send information encoded as a sequence of images. Liquid crystal displays (LCDs) and light emitting diodes (LEDs) are some examples of intensity modulators (IM). The receiver contains an array of photo-detectors that detects the coded images. Charge-coupled device (CCD) cameras, arrays of photodiodes, Complimentary Metal-Oxide-Semiconductor imagers are some of the devices which can be used as Direct Detection (DD) receivers. The Pixelated Optical systems are used in situations that require strict signal containment. Examples of such applications include communications within a room or in some enclosure, or perhaps between two communicating parties concerned about radiating to an unauthorized third party such as in military applications.

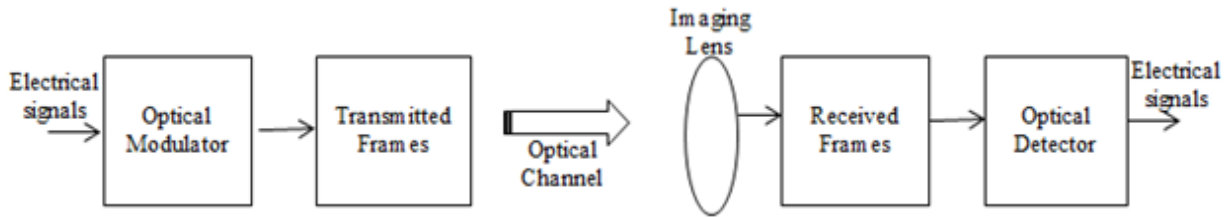


FIG. 1 ILLUSTRATION OF PIXELATED MIMO WIRELESS COMMUNICATION SYSTEM

III. VIGNETTING

The performance of pixelated multiple-input multiple-output optical wireless communication systems can be impaired by vignetting. Vignetting is the gradual illumination fall-off from the centre to the corners of the received images. It is a reduction of an image's brightness or saturation at the periphery compared to the image center



ORIGINAL IMAGE



VIGNETTED IMAGE

FIG. 2. ILLUSTRATION OF VIGNETTING EFFECT

In a pixelated system, the information is encoded on the intensity of the transmitted images, and hence vignetting can result in incorrect data recovery at the receiver. Vignetting causes attenuation, energy inefficiency and InterCarrier Interference (ICI) in the spatial frequency domain, resulting in bit errors, thereby reducing the Bit Error Rate (BER) Performance of the Pixelated MIMO Optical System. The most prominent factors that contribute to vignetting in the Pixelated MIMO Optical Wireless Systems are,

Depending on the spatial positions of the IM transmitter elements, there is a variation in the intensity received by the receiver imaging lens.

- Cosine-fourth radiometric effect.
 - Blocking of the transmitted light by the receiver elements.
 - Improper Source Illuminations.
 - Unpredictable Channel Noise and Interferences.
- The Factors that determine the level of Vignetting are,
- Geometry of the lens optics.
 - Aperture settings.
 - Other optical properties of the receiver.

IV. SPATIAL OFDM SYSTEM

Spatial OFDM is used in most of the Pixelated Optical wireless systems. Fig. 3.shows the general block diagram of Spatial OFDM system. It is the extension of the conventional OFDM to the 2D-spatial domain. The input data bits are initially modulated using the N-QAM modulation. The output QAM symbols are used as the inputs to an IFFT block that brings the signal into the time domain. The IFFT takes in N symbols at a time where N is the number of subcarriers in the system.

A cyclic prefix (CP) and a cyclic postfix (CPO) can be appended around the borders of the spatial OFDM transmitted frames, to make them tolerant to linear misalignment within the range of CP and CPO. The IM modulator is used for converting the electrical signals into optical light signals. The reverse process of the transmitter is performed in the receiver. The channel noise composed of shot noise and thermal noises modeled as Additive White Gaussian Noise (AWGN).

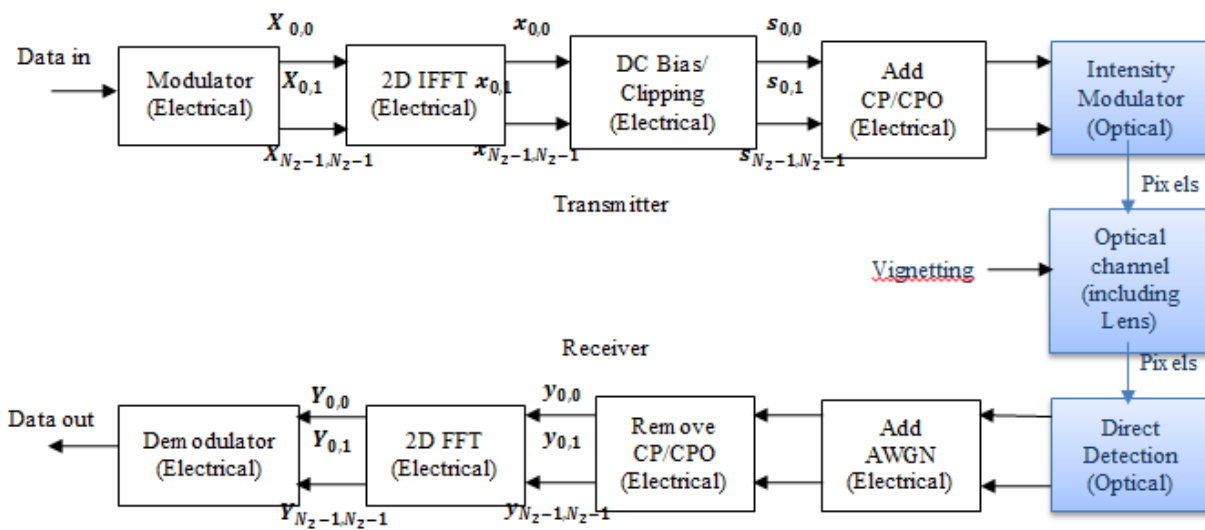


FIG. 3. BLOCK DIAGRAM OF A SPATIAL OFDM SYSTEM

V. TECHNIQUES APPLIED

In this paper, three algorithms are proposed. An equalization technique is proposed for the elimination of Vignetting effects. Exhaustive Search Algorithm is proposed for reducing the power consumption. Error Control coding (ECC) is applied for reducing the transmission Bit errors.

5.1 Vignetting Estimation Technique

Vignetting Estimation and Equalization can be used in the Spatial OFDM-based Optical wireless systems to reduce the effects of Vignetting. Linear Minimum Mean Square Error (LMMSE) algorithm is used. The criterion used in this algorithm is to minimize the Mean Square Error (MSE) between the desired equalizer output and the actual equalizer output.

If the time domain channel vector g is Gaussian and uncorrelated with the channel noise, the frequency-domain LMMSE estimate of g is given by

$$h_{LMMSE} = FR_{gy}R_{yy}^{-1}y \quad \text{where}$$

$$F = \begin{bmatrix} W_N^{00} & \dots & W_N^{0(N-1)} \\ \vdots & \ddots & \vdots \\ W_N^{(N-1)0} & \dots & W_N^{(N-1)(N-1)} \end{bmatrix} \text{ and}$$

$$W_N^{nk} = \frac{1}{N} e^{-j2\pi \frac{n}{N}k} \tag{1}$$

where R_{gy} and R_{yy} is cross covariance matrix between g and y and the auto-covariance matrix of y respectively.

5.2 Exhaustive Search Algorithm

OFDM is spectrally efficient but power inefficient due to the large peak-to-average power ratio (PAPR) inherent in the OFDM signals. A large power ratio value also makes the signal vulnerable to nonlinearities in the transmission. The partial transmit sequence (PTS) technique is employed for power reduction performance. In the PTS scheme, the input data is divided into smaller disjoint sub-blocks. Each sub-block is multiplied by rotating phase factors. The sub-blocks are then added to form the OFDM symbol for transmission. The PTS scheme designs an optimal phase factor for a sub-block set that minimizes the power ratio.

The exhaustive search algorithm (ESA) is employed to find the best phase factor. The ESA performs an exhaustive search over all combinations of the allowed phase factors and has exponential search complexity with the number of sub-blocks.

5.3 Error Control Coding

Error Control Coding (ECC) or Forward Error Correction (FEC) a technique used for controlling errors in data transmission, thereby reducing the bit errors and improving the BER performance. Low-Density Parity-Check (LDPC) code is a linear error correcting code, which uses redundancy to increase the chance of recovering from channel errors. The sub-optimal decoding techniques are employed for the LDPC decoding process.

An (n, k) LDPC code is functionally are defined by a sparse parity-check matrix. The Parity-check matrix H is given by the form, $[-P^T | I_{n-k}]$.

The Generator Matrix G is obtained by, $[I_k | P]$. All valid codeword's are obtained by multiplying all possible k-bit strings by G. The row space of G is orthogonal to H such that,

$$GH^T = 0 \tag{2}$$

VI. RESULTS

The Effect of Vignetting in Spatial OFDM-based Pixelated Optical wireless systems is simulated and its elimination using the proposed LMMSE technique, Exhaustive search algorithm and LDPC coding technique for various constellation sizes is simulated using MATLAB simulation tool in windows 8 Operating Platform and the following results are obtained.

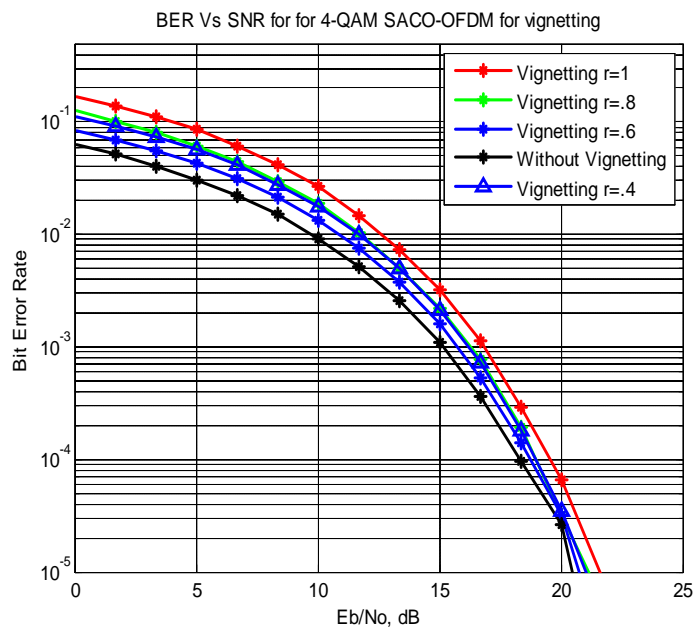


FIG. 4. BER PERFORMANCE FOR 4-QAM SACO-OFDM

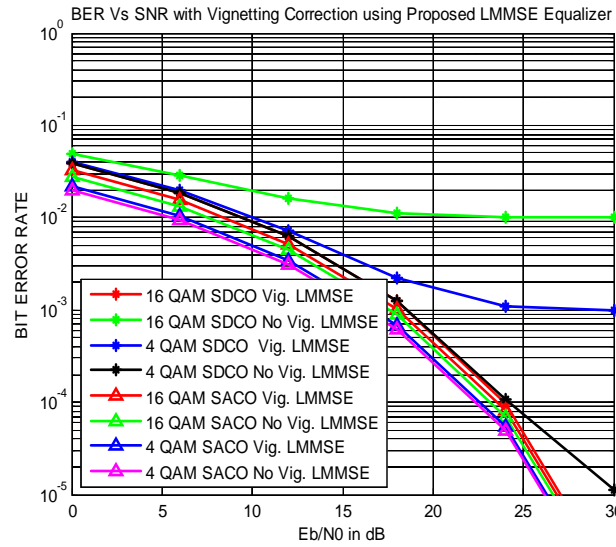


FIG. 5. BER VERSUS E_b/N_0 USING PROPOSED LMMSE EQUALIZER

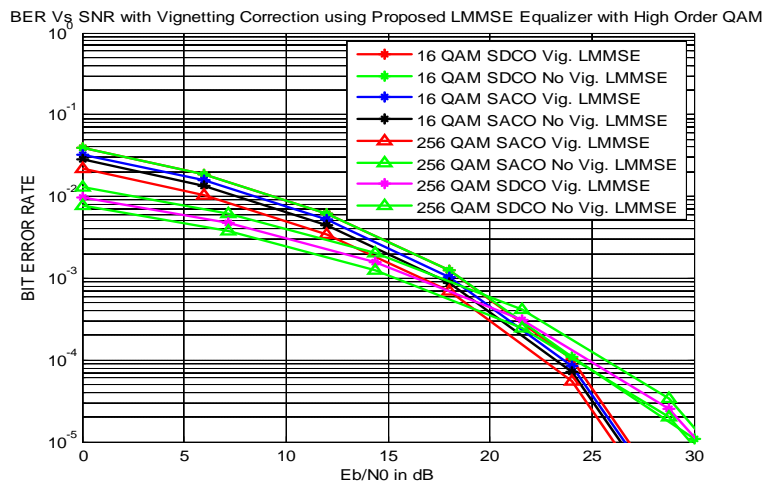


FIG. 6. BER PERFORMANCE OF PROPOSED LMMSE EQUALIZER WITH HIGHER ORDER QAM

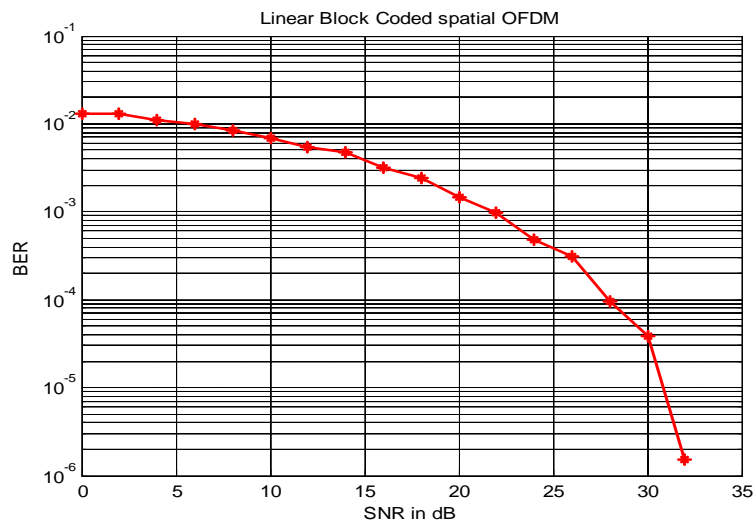


FIG. 7. BER PERFORMANCE IN LDPC- CODED SPATIAL OFDM

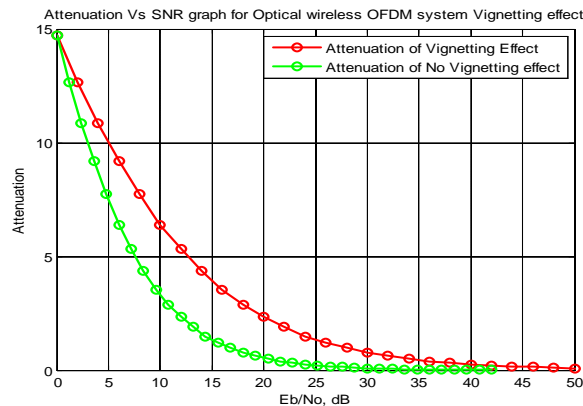


FIG. 8. ATTENUATION PROFILE WITH AND WITHOUT VIGNETTING

Fig. 4. shows the BER vs SNR performance of 4-QAM SACO-OFDM for no vignetting and various levels of vignetting. Fig. 5. shows the BER performance of the system when the proposed LMMSE equalizer is implemented. Fig. 6. shows the BER performance when higher order QAM is implemented in the system with the proposed LMMSE equalizer. Fig. 7. shows the BER performance when the system is LDPC channel-coded. Fig. 8. shows that the attenuation level is decreased when the proposed LMMSE equalizer is used in the system.

VII. CONCLUSION

The Proposed work analyzes the impact of vignetting on a Spatial OFDM based pixelated system. The effects of Vignetting include attenuation, increased power ratio, ICI and BER degradation. The LMMSE algorithm is applied to reduce the overall effect of vignetting. The Exhaustive search algorithm is implemented to increase power efficiency. The ECC coding method is employed to cut down the bit errors. The proposed technique shows improved system performance compared to the previous works. The results obtained implies that, by applying the proposed technique the optical system shows reduced attenuation, ICI and improved BER performance.

REFERENCES

- [1] D. O'Brien, R. Turnbull, H. L. Minh, G. Faulkner, O. Bouchet, P. Porcon, M. E. Tabach, E. Gueutier, M. Wolf, L. Grobe, and J. Li, "High-speed optical wireless demonstrators: Conclusions and future directions," *J. Lightw. Technol.*, vol. 30, no. 13, pp. 2181–2187, Jul. 2012.
- [2] J. Kahn and J. Barry, "Wireless infrared communications," *Proc. IEEE*, vol. 85, pp. 265–298, 1997.
- [3] D. O'Brien, M. Katz, P. Wang, K. Kalliojarvi, S. Arnon, M. Matsumoto, R. Green, and S. Jivkova, "Short-range optical wireless communications," in *Technologies for the Wireless Future: Wireless World Research Forum*, 2nd ed, New York, NY, USA: Wiley, 2006, vol. 2, pp. 277–296.
- [4] K. Langer and J. Grubor, "Recent developments in optical wireless communications using infrared and visible light," presented at the *Int. Conf. Transparent Optical Networks*, Rome, Italy, Jul. 2007.
- [5] R. J. Green, H. Joshi, M. D. Higgins, and M. S. Leeson, "Recent developments in indoor optical wireless systems," *IET Commun.*, vol. 2, pp. 3–10, 2008.
- [6] M. Kavehrad, "Sustainable energy-efficient wireless applications using light," *IEEE Commun. Mag.*, vol. 48, no. 12, pp. 66–73, Dec. 2010.
- [7] S. Hranilovic, *Wireless Optical Communication Systems*. New York, NY, USA: Springer, 2004.
- [8] H. Elgala, R. Mesleh, and H. Haas, "Indoor optical wireless communication: Potential and state-of-the-art," *IEEE Commun. Mag.*, vol. 49, no. 9, pp. 56–62, Sep. 2011.
- [9] L. Zeng, D. O'Brien, H. Minh, G. Faulkner, K. Lee, D. Jung, Y. Oh, and E. T. Won, "High data rate multiple input multiple output (MIMO) optical wireless communications using white LED lighting," *IEEE J. Sel. Areas Commun.*, vol. 27, no. 9, pp. 1654–1662, Dec. 2009.
- [10] H. B. C. Wook, T. Komine, S. Haruyama, and M. Nakagawa, "Visible light communication with LED-based traffic lights using 2-dimensional image sensor," in *Proc. IEEE Consumer Commun. Netw. Conf.*, Jan. 8–10, 2006, pp. 243–247.
- [11] A. Ashok, M. Gruteser, N. B. Mandayam, J. Silva, M. Varga, and K. J. Dana, "Challenge: Mobile optical networks through visual MIMO," in *Proc. Int. Conf. Mobile Comput. Netw.*, Chicago, IL, USA, Sep. 20–24, 2010, pp. 105–112.
- [12] S. Hranilovic and F. R. Kschischang, "Short-range wireless optical communication using pixelated transmitters and imaging receivers," in *Proc. IEEE Int. Conf. Commun.*, 2004, pp. 891–895.