ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 10, October 2016

Performance Analysis of Flip OFDM in Optical Wireless Communication Using Iterative Receiver

M. Prathibha, Dr. B. Brahma Reddy

***Abstract*— To ensure nonnegative signals in optical wireless communication (OWC) systems, flipped orthogonal frequency division multiplexing (Flip-Orthogonal Frequency Division Multiplexing) transmits the positive and negative parts of the signal over two successive OFDM sub frames (positive subframe and negative subframe, separately). The conventional receiver for Flip-OFDM retrieves the information by subtracting the negative subframe from the positive. In any case, the signal analysis demonstrates that both the subframes contain the transmitted information and can be utilized together to decode the data. An iterative receiver is then proposed to enhance the transmission performance of Flip-OFDM by utilizing the signals in both sub frames. Simulation results proved that the proposed iterative receiver provides significant signal to noise ratio (SNR) gain over the conventional receiver.**

***Index Terms*— Flip-OFDM, orthogonal frequency division multiplexing (OFDM), Optical wireless communication (OWC).**

I. Introduction

In past days people used to communicate with distant counterparts by make usage of traditional approaches like sending data with flying creatures, sending individuals as minister to convey the information. Most of the researchers termed 21st century as Communication field because of the top of the line mechanical advancement in this area which makes communication fast and reliable. The serious examination arranged correspondence into two classes a) wire based correspondence b) remote based interchanges. Wire based interchanges is considered as most helpful instrument in world wars to pass on data starting with one end then onto the next in 1940's and optical fiber assumes a significant part in wire based correspondence component and after fruition of war the predominance of United States of America (USA) and Union of Soviet Socialist Republics (USSR) over the world makes the exploration on correspondence so quick that in two decades correspondence research develops from everyday life correspondence to satellite correspondence and this improvement for the most part as a result of remote correspondence.

Usually radio frequencies (RF) are used for wireless communications. Recently optical wireless communications (OWC) has emerged as an alternative to radio frequencies.OWC will uses infrared (IR) transmitters. This is because infrared systems present certain advantages over RF systems for short-range indoor communications, including no electromagnetic interference concerns, ease of signal confinement for security purposes, and license-free operations. However, the use of white light emitting diodes (LEDs) is increasingly becoming an attractive alternative to IR since white LEDs can be used to illuminate and communicate at the same time. OWC systems using white LEDs are referred to as visible light communications (VLC). There are a few notable advantages of optical frequencies. They provide practically unlimited and license -free bandwidth to access, up to several hundred THz. IR and visible light provide higher security than RF since both types of signals do not penetrate through walls, and do not get interfered from other rooms or buildings. Both can be used in areas where Radio Frequency communications is restricted, such as airplanes and hospitals. In spite of that, OWC still possesses some drawbacks. One restriction is that the available optical transmit power is limited by eye safety standards.

In Flip-OFDM the conventional receiver is used to recover the data by subtracting the negative signal block from the positive signal block. This method is straightforward and easy. However, it increases the noise variance of the received symbols and it will make the performance much worse than that of bipolar OFDM with the same modulation method. But the algorithm does not make utilize the signal structures. In order to overcome this problem an iterative receiver is proposed for Flip-OFDM by fully exposing the structures of the received signals. Simulations show that the proposed iterative receiver is higher-up to conventional receiver.

Notations: Italic bold letters denote column vectors. More specifically, time domain vector can be denoted in a lowercase letter such as v, and the uppercase letter such as V indicates the corresponding frequency-domain vector. Non italic letter with bold such as A indicates a matrix. Specially, I and 0 represent the identity and zero matrices with appropriate dimensions, respectively. $(.)^*$, $(.)^T$, $(.)^H$, $|.|$ and sign(.) denote conjugate, transpose, Hermitian transpose, absolute value and sign (for convenience, sign(0) = 1 is defined), respectively. The n-th element of a vector v is indicated by v (n). diag(v) is a diagonal matrix along with v on the main diagonal.

II. SYSTEM MODEL

The piece outline of a Flip-OFDM transmitter with N subcarriers is illustrated in Fig. 1. To ensure that the time-domain signal is real in Intensity modulation/Direct Detection (IM/DD) systems, the input data vector $X = [X(0), X(1), ...X(N-1)]^T$ should satisfy the Hermitian symmetry property, i.e.,

$$X^*(N-k), k = 1, 2, ..., N/2-1 \quad (1)$$

Note that X(0) and X(N=2) are normally set to zero since the DC part of OFDM signal is left unused in practical applications. Thus, the time-domain signal vector x = [x(0),x(1),…., x(N-1)] after inverse fast Fourier transform (IFFT) operation can be represented as

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) \exp(j2\pi kn/N)$$
$$= \frac{2}{\sqrt{N}} \sum_{k=1}^{N/2-1} \mathrm{Re}[X(k) \exp(j2\pi kn/N)]$$

(2)

The signal x(n), which is real and bipolar, can be decomposed as

$$x(n) = x^+(n) + x^-(n),$$

(3)

where the positive part and the negative part are defined as

$$x^+(n) = \begin{cases} x(n), x(n) \geq 0 \\ 0, x(n) < 0 \end{cases} \quad (4)$$

$$x^-(n) = \begin{cases} x(n), x(n) < 0 \\ 0, x(n) \geq 0 \end{cases}$$

(5)

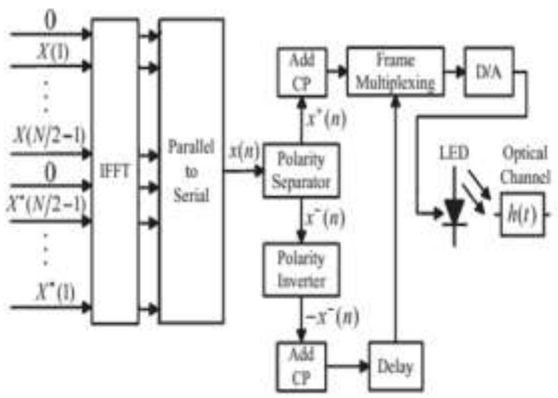


Fig.1. Block diagram of a Flip-OFDM transmitter.

To ensure a nonnegative time-domain signal, the two parts $x^+(n) = [x^+(0), x^+(1), ..., x^+(N-1)]^T$ and $x^-(n) = [x^-(0), x^-(0), ..., x^-(N-1)]^T$ are independently transmitted more than two back to back OFDM subframes. The positive segment x^+ is transmitted in the principal subframe (positive subframe), while the flipped negative segment - x^- is transmitted in the second subframe (negative subframe). A case of the time space signals in Flip-OFDM is delineated in Fig. 2. In the wake of engendering through the optical channel, the unipolar time space sign is gotten by a photodetecter. Assuming the channel impulse response $h = [h(0), h(1), ...h(N-1)]^T$ is consistent more than two successive OFDM subframes, the got signal vectors in the recurrence area are given by

$$Y^+ = HX^+ + Z^+,$$

(6)

$$Y^- = -HX^- + Z^-,$$

(7)

Where $H = diag(W_N h)$, $X^+ = W_N x^+$, $X^- = W_N x^-$, W_N is the N x N discrete Fourier transform(DFT) matrix, Z^+ and $Z^- \sim N(0, \sigma^2 I)$, represent the noise vectors of the two subframes, respectively.

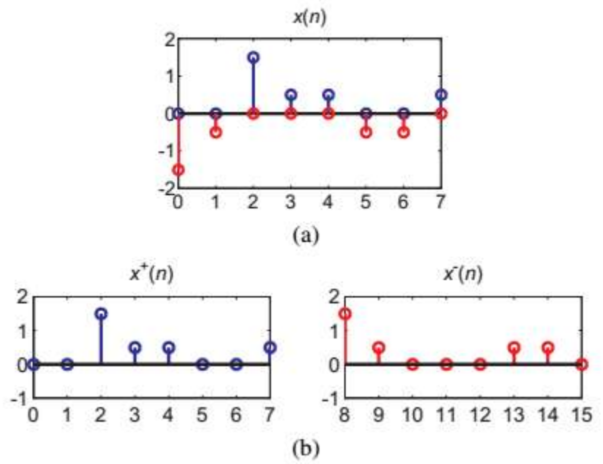


Fig. 2. An example of the time domain signals in Flip-OFDM (N =8). (a) x(n). (b) $x^+(n)$ and (c) $x^-(n)$.

III. RECEIVER DESIGN

A. Conventional Receiver

A receiver is proposed for Flip-OFDM, which subtracts the negative subframe from the positive one to decipher the information. To encourage the accompanying portrayals, the recipient proposed is named as the conventional receiver in this paper. Subtracting (7) from (6) yields

$$Y^+ - Y^- = HX^+ + HX^- + Z^+ - Z^-$$
$$= HX + Z,$$

(8)

where $Z = Z^+ - Z^-$. Then, the conventional receiver can be described as

$$\hat{X}_{conv} = dec[H^{-1}Y^+ - H^{-1}Y^-].$$

(9)

where dec[.] indicates the decision of the detector.

B. Proposed Receiver

The conventional receiver is basic and direct, however it doesn't completely misuse the structures of the received signals. The conventional receiver is simple and direct, but it does not fully exploit the structures of the received signals. In the accompanying, an another receiver is proposed by establishing the relationship between the received signals Y^{+}, Y^{-} and the input data X .

Since $|x|$ can be expressed as

$$|x| = S(X)x$$

$$= S(X)W_N^H X, \quad (10)$$

Where S(X) is defined as

$$S(X) = diag\{sign(x)\}$$
$$= diag\{sign(W_N^H X)\}, \quad (11)$$

One can rewrite (4) as

$$x^{+} = \frac{x+|x|}{2}$$
$$= \frac{x+S(X)W_N^H X}{2} \quad (12)$$

From (4.12) and $X^{+} = W_N x^{+}$, it is easy to get

$$X^{+} = W_N \frac{x+s(X)W_N^H X}{2}$$
$$= \frac{I+W_N S(X)W_N^H}{2} \quad (13)$$

Substituting (13) into (6) gives

$$Y^{+} = \frac{H+HW_N S(X)W_N^H}{2} X + Z^{+} \quad (14)$$

Similarly, by using (7) and $x^{-} = \frac{x-|x|}{2}$, the relationship between Y^{-} and X can be derived as

$$Y^{-} = \frac{HW_N S(X)W_N^H - H}{2} X - Z^{-} \quad (15)$$

(14) and (15) show the structures of the received signals in the two subframes, respectively. They can be concatenated to

$$\begin{pmatrix} Y^{+} \\ Y^{-} \end{pmatrix} = \frac{1}{2}\begin{pmatrix} H+HW_N S(X)W_N^H \\ HW_N S(X)W_N^H - H \end{pmatrix} X + \begin{pmatrix} Z^{+} \\ Z^{-} \end{pmatrix} \quad (16)$$

In view of (16), a few techniques are accessible to recuperate the information X. In this report, the zero-forcing(ZF) estimator is decided for its low complexity and effortlessness. Indicating

$$G(X) = \frac{1}{2}\begin{pmatrix} H+HW_N S(X)W_N^H \\ HW_N S(X)W_N^H - H \end{pmatrix} \quad (17)$$

the ZF matrix can be derived as

$$T_{ZF}(X) = \left[G^H(X)G(X)\right]^{-1} G^H(X) \quad (18)$$

Then, the estimate of *X* is given by

$$\tilde{X} = T_{ZF}(X)\begin{pmatrix} Y^{+} \\ Y^{-} \end{pmatrix} \quad (19)$$

The matrix $T_{ZF}(X)$ is dependent on the data vector *X*, an iterative receiver can thus be proposed as

$$\tilde{X}^{(i)} = \begin{cases} dec[H^{-1}Y^{+} - H^{-1}Y^{-}], i = 0 \\ dec\{T_{ZF}(\tilde{X}^{(i-1)})\begin{pmatrix} Y^{+} \\ Y^{-} \end{pmatrix}\}, i = 1,........K \end{cases} \quad (20)$$

Where *i* is the iteration index and *K* is the maximum number of iterations. Note that, when *K*=0, the proposed iterative receiver in (20) is equal to the conventional receiver in (9)

Especially, in line-of-light(LOS) channels, the channel response can be expressed as

$$h(n) = c\delta(n) \quad (21)$$

where c is a constant and $\delta(n)$ is the dirac delta function. Since c scales the signal-to-noise ratio(SNR) only, without loss of generality, putting c equals to one to simplify the derivations. In this case, one can obtain H=I, $G^H(X)G(X) = I$ and $T_{ZF}(X) = G^H(X)$. Therefore, the estimate of X and be simplified as

$$\tilde{X}_{LOS} = \frac{1}{2}[I+W_N S(X)W_N^H]Y^{+} + \frac{1}{2}[W_N S(X)W_N^H - I]Y^{-} \quad (22)$$

and the iterative receiver becomes

$$\tilde{X}_{LOS}^{(i)} = \begin{cases} dec[Y^{+} - Y^{-}], i = 0 \\ dec\{\frac{1}{2}[I+W_N S(\tilde{X}_{LOS}^{(i-1)})W_N^H]Y^{+} \\ +\frac{1}{2}[W_N S(\tilde{X}_{LOS}^{(i-1)})W_N^H - I]Y^{-}\}, i = 1,........,K \end{cases} \quad (23)$$

By applying the additive property of DFT, the comparable time-domain form of (4.22) can be stated as

$$\tilde{x}_{LOS}(n) = \frac{1}{2}\{1+sign[x(n)]\}y^{+}(n)$$
$$+\frac{1}{2}\{sign[x(n)]-1\}y^{-}(n) \quad (24)$$

It can be seen from (24) that in LOS channels, the main contrast between the conventional receiver and the proposed receiver is the weight multiplied by $y^{+}(n)$ or $y^{-}(n)$. This is extremely valuable for lessening the implementation expense of the proposed receiver in LOS channels.

C. Computational Complexity

In this area, we overview the computational complexity of various receivers with order notation. Since the conventional receiver and the noise filtering receiver, in both incorporate a single Fast Fourier Transform (FFT) operation, both of them has a complexity of O(N log N). For the proposed iterative receiver, the computational complexity is identified with the channel characteristics. In non-line-of-sight (NLOS) channels, the iterative receiver has a complexity of O(N^3) per cycle because of the matrix inversion of the Zero Force(ZF) estimator. In LOS channels, the multifaceted nature of the iterative collector is O(N log N)) per iteration because the matrix inversion is avoided. It ought to be noticed that the iterative receiver needs extra IFFT operations with complexity of O(N log N) to evaluate S(X) in either LOS channels or NLOS channels.

IV. SIMULATION RESULTS

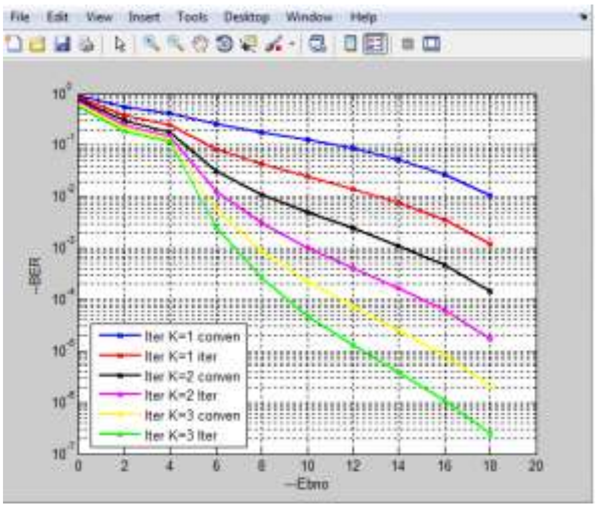
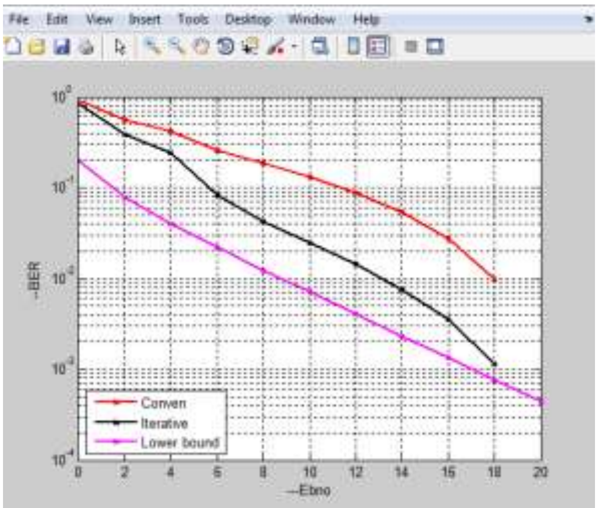
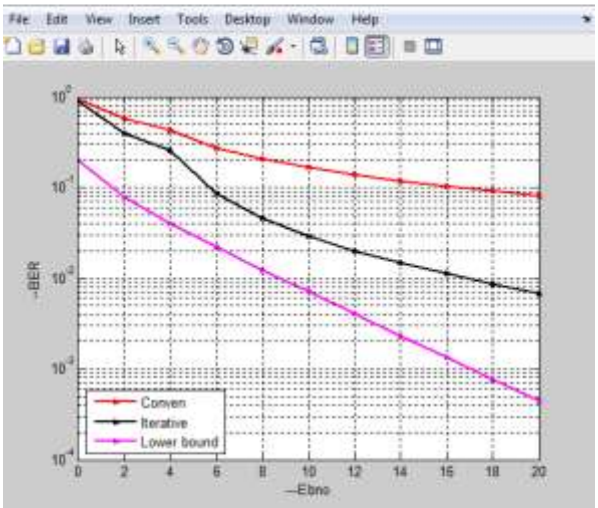


Fig. 3 BER performance of the iterative receiver with different iteration numbers and comparison between conventional receiver and iterative receiver.



(a)



(b)

Fig. 4 BER comparison of iterative receiver and conventional receiver for Flip-OFDM.
(a)LOS channels (b) NLOS channels.

Fig. 3 demonstrates the BER execution of the iterative receiver with different iteration numbers for LOS Channels. It can be clearly seen that the performance of the iterative receiver can be improved by increment the iteration number K over conventional receiver.

It can be seen from Fig.4 that the iterative receiver achieves noticeable gain over the conventional receiver in any case. Specifically, at the BER of 10^{-4}, the iterative receiver gives 0.6 dB and 1 dB gains over the conventional receiver in LOS.

V. CONCLUSION

An iterative receiver is proposed for Flip OFDM in Intensity Modulation/Direct Detection(IM/DD) based Optical Wireless Communication systems. In order to improve the receiver performance, the iterative receiver obtains the additional diversity gain by utilizing the signals in both the positive subframe and negative subframe. The simulation results show that the iterative receiver with only two recurrence provides a significant SNR gain. The results presents that the signal to noise ratio in Line of Sight (LOS) channel and Non Line of Sight(NLOS)channel is more compared to existing conventional receiver.

REFERENCES

[1] Li X., Vucic J., Jungnickel V., Armstrong J. "On the capacity of intensity-modulated direct detection systems and the information rate of ACOOFDM for indoor optical wireless applications" IEEE Trans. Comm., Mar. 2002, pp. 799 −809.

[2] Elgala. H., Mesleh. R., Haas. H. "Indoor broadcasting via white LEDs and OFDM" IEEE Trans. on Cons. Electron., Aug. 2009,pp.1127 −1134.

[3] J. Armstrong, "OFDM for optical communications," Journal of Lightwave Technology, vol. 27, no. 3, pp. 189–204, Feb. 2009.

[4] D. J. Barros, S. K. Wilson, and J. M. Kahn, "Comparison of orthogonal frequency-division multiplexing and pulse-amplitude modulation in indoor optical wireless links," IEEE Transactions on Communications, vol. 60, no. 1, pp. 153–163, Jan. 2012.

[5] N. Huang, J.-B. Wang, J. Wang, C. Pan, H. Wang, and M. Chen, "Receiver design for PAM-DMT in indoor optical wireless links,"

IEEE Photonics Technology Letters, vol. 27, no. 2, pp. 161–164, Jan. 2015.
[6] J. Armstrong and B. Schmidt, “Comparison of asymmetrically clipped optical OFDM and DC-biased optical OFDM in AWGN,” IEEE Communications Letters, vol. 12, no. 5, pp. 343–345, May 2008.
[7] J. Armstrong and A. Lowery, “Power efficient optical OFDM,” Electronics Letters, vol. 42, no. 6, pp. 370–372, Mar. 2006.
[8] S. C. J. Lee, S. Randel, F. Breyer, and A. M. Koonen, “PAM-DMT for intensity-modulated and direct-detection optical communication systems,” IEEE Photonics Technology Letters, vol. 21, no. 23, pp. 1749–1751, Dec. 2009.
[9] N. Fernando, Y. Hong, and E. Viterbo, “Flip-OFDM for optical wireless communications,” in Proc. 2011 IEEE Information Theory Workshop (ITW), 2011, pp. 5–9.
[10] D. Tsonev and H. Haas, “Avoiding spectral efficiency loss in unipolar OFDM for optical wireless communication,” in Proc. 2014 IEEE International Conference on Communications (ICC), pp. 3336–3341.
[11] N. Fernando, Y. Hong, and E. Viterbo, “Flip-OFDM for unipolar communication systems,” IEEE Transactions on Communications, vol. 60, no. 12, pp. 3726–3733, Dec. 2012.
[12] Kahn J.M, Barry J.R. “Wireless infrared communications” Proc. of IEEE, Feb. 1997, pp. 265 −298.
[13] E. G. Larsson, “MIMO detection methods: How they work,” IEEE Signal Processing Magazine, vol. 26, no. 3, pp. 91–95, May 2009.
[14] J. Karout, E. Agrell, K. Szczerba, and M. Karlsson, “Optimizing constellations for single-subcarrier intensity-modulated optical systems,” IEEE Transactions on Information Theory, vol. 58, no. 7, pp. 4645– 4659, July 2012.
[15] Tanaka. Y., Komine. T., Haruyama S., Nakagawa M. “Indoor visible light data communication system utilizing white LED lights,” IEICE Trans. on Comm., Aug. 2003, E86 − B, pp.2440 −2454.

AUTHOR PROFIE:

M.PRATHIBHA, Mtech,

Present pursuing Master of techonology in Vignana Bharathi Institute of Technology(VBIT), Aushapur(V**),** Ghatkesar(M), R.R Dist TS -501301, INDIA**.**

Dr. B. BRAHMA REDDY, HOD of ECE Department, Mtech, Ph.D

He is having the 24 Years of Industrial Experience in that 22 years of Research having 6 years of teaching experience.. Did Mtech from IIT-Madras, PGDBA from Pondicherry University and PhD from JNTUH. Present working as HOD of ECE in Vignana Bharathi Institute of Texhnology(VBIT), Aushapur(V**),** Ghatkesar(M), R.R Dist TS -501301, INDIA.