A Novel Idea For Enhancing The Performance Of HCM Based VLC Systems

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***Abstract*—**A new method is proposed for optimizing the performance of Hadamard coded modulation(HCM)based systems in visible light communication.. Prior to HCM,OFDM was used in Wireless Optical Communication(WOC) for data modulation whereas HCM was used as precoder in OFDM systems. But the constraint of optical sources used lead to signal distortion at the output.. Hence HCM is used as an alternative technique for systems that require high average power. Here data is modulated using Fast Walsh Hadamard Transform (FWHT).On-off keying (OOK) along with thresholding method is applied to the HCM system for improving its performance. Both the existing and modified system performance is evaluated in terms of various performance paramaters .

Keywords*—HCM,VLC,on-off keying,Fast Walsh Hadamard Transform,integrate and dump,*

I. INTRODUCTION

The visible light communication(VLC) is an emerging technology that uses light instead of radio frequency signals for data transmission. The unregulated bandwidth available in VLC reduces the traffic on the RF spectrum. It is also known as short range optical wireless communication. The objective of VLC is to increase data rates in wireless communication and to have better performance of networks especially for indoor networks using light emitting diode(LED) lamps.LED has many benefits such as low power consumption ,small size ,long life, low heat, low heat radiation .So they are used in numerous applications like traffic lights, advertisement displays, indoor lighting equipment and so on[10].

However ,using LEDs as sources add restrictions on the modulation schemes and codes that can be used. The limitations of these LEDs include limited peak optical power, nonlinear transfer function, and limited modulation bandwidth. Therefore modulation and coding schemes with high spectral efficiencies are required and coding schemes with high spectral efficiencies are required to provide high data rate connection.[1].

OFDM(Orthogonal frequency division multiplexing) is an efficient modulation technique for high data rate communications and has been adapted to work in energy efficient optical communications[3].But the peak power constraint of the optical sources limits the high peaks of the output signal resulting in signal distortion. PAPR (Peak to average power ratio) reduction techniques can alleviate this problem .Hadamard modulation was thus proposed because of their low PAPR and high illumination levels in VLC systems. This project aims to optimize the performance of such HCM (Hadamard coded modulation) based VLC systems.

A modified HCM system is proposed which is found to be better when compared to existing HCM system. The modified system uses OOK (on-off keying) to modulate the input data and at the receiver an integrate and dump method is used to recover the demodulated signal.

In HCM ,pulse amplitude modulation(PAM) was used to modulate input data whereas here on-off keying is used .At the receiver using integrate and dump process along with thresholding, the received signal is demodulated. Both the existing and proposed methods are then compared in terms of various performance parameters such as bit error rate (BER), energy efficiency etc. The paper is organized as follows, section II gives an overview of existing HCM system followed by section III where modified HCM system is provided. The performance comparison of both the existing and proposed method is discussed in section iv followed by a discussion on results and conclusion in section V.

II. HADAMARD CODED MODULATION

Hadamard coded modulation uses a binary Hadamard matrix to modulate the input data. Suppose H_N be an N^{th} order binary Hadamard matrix , obtained by replacing -1 by 0 in the original {−1, 1} Hadamard matrix[5]. The components of u are assumed to be modulated using M-ary pulse amplitude modulation (PAM), i.e.,.

$$u_n \in \{0,1/M\text{-}1 ,2/M\text{-}1,...1\} \quad \text{for } n = 0,1,\ldots N\text{-}1. \quad (1)$$

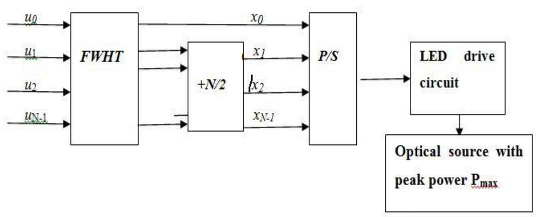

Fig.1 Block diagram of HCM transmitter

In the transmitter structure, shown in Fig.1, the HCM symbols generated are sent to an amplitude modulator that then modulates the optical source. This structure, which we call the single-source structure, can be used with power-line communication (PLC) integrated VLC networks, where the data is send to the LED bulbs via the power lines and each component of the LED array cannot be modulated separately. In the single-source structure, the nonlinear transfer function of the optical source causes unequal spacing between the transmitted power levels, which makes the symbols more susceptible to noise, and therefore, a pre-distorter is required to make the power levels equal. A control circuit is also needed to compensate for the drift due to the thermal changes, which leads to an increased complexity of the transmitter[5].

The transmitted vector x is obtained from the data vector as

$$x = uH_N + (1-u)\,\bar{H}_N \qquad (2)$$

The equation can be rewritten as

$$x = u(H_N - \bar{H}_N) + N/2[0\ 1\ 1\ ......1] \qquad (3)$$

where the second term is obtained from the product of a 1 * N vector of all ones and $\bar{H}_N$ .The matrix $(H_N - \bar{H}_N)$ is the bipolar Hadamard matrix, and hence, the first term in eq (3) is the Walsh-Hadamard transform of the vector u.

Using an FWHT of size N,the hadamard transform is applied to the input data , which has a complexity of N $\log_2$ N, and then a constant value of N/2 is added to N − 1 elements to generate x. Here N − 1 rows of H_N are only used that have a weight of N/2 to modulate the data, and the first row of the Hadamard matrix which has all ones are ignored. Hence the first component of u gets set to zero, and the rate of M-PAM HCM therefore is (N − 1)/N $\log_2$M . There exists a fixed cross-correlation between the remaining N − 1 rows, which helps in removing the interference of the Hadamard codewords among each other at the receiver side[5][1].

The decoded vector v is obtained from the received vector y as

$$v = 1/N(yH_N^T - y\bar{H}_N^T) + 1/2[1-N\ ,1,1....1] \qquad (4)$$

which can be realized by an inverse FWHT (IFWHT) as shown in Fig.2

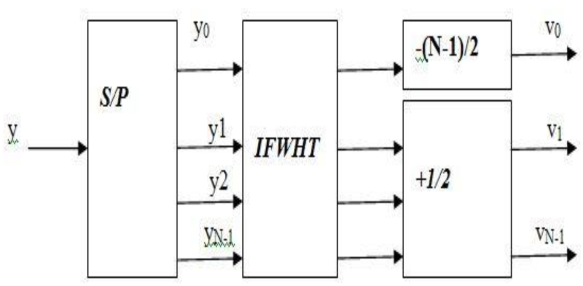

Fig.2 Block diagram of HCM receiver

The noise due to the channel, n, is assumed to be additive white Gaussian noise (AWGN), and the output signal is given by y = h * x + n, where h = {h(k)} is the discrete-time equivalent impulse response of the channel and * denotes the convolution operation. For an ideal non-dispersive channel with impulse response.

$$h(k)=\{1,\text{for } k = 0$$
$$= \{0,\text{ for } k \neq 0 \qquad (5)$$

the decoded data can be rewritten as

$$v = (u+1/2[1-N,1,1....1])+\tilde{n} \qquad (6)$$

where $\tilde{n}$ is a 1*N noise vector with independent components

For average power levels less than P0/2, the HCM signals are not distorted by the LED nonlinearity and the performance of HCM is only limited by the noise.

III. MODIFIED HCM SYSTEM

In VLC systems where high average optical powers are required for illumination, some forms of OFDM can suffer from signal clipping. This problem can be alleviated by using peak to average power ratio (PAPR) reduction techniques that trade-off complexity and energy inefficiency .Hadamard matrices can be used as precoders in OFDM systems to decrease the PAPR, reduce BER and increase the resistance of the signals against frequency selective fading. A multilevel modulation technique named HCM (Hadamard Coded Modulation) that uses the Hadamard matrices as a modulation technique rather than a precoder. In this system the data is modulated using a fast Walsh- Hadamard transform (FWHT) and the receiver uses an inverse fast Walsh-Hadamard transform (IFWHT) to decode the received signals.The proposed system uses OOK (on-off keying) to modulate the input data and at the receiver an integrate and dump method is used to recover the demodulated signal.

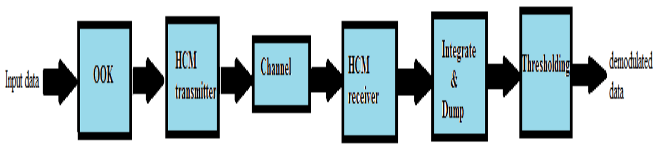

Fig.3 Block diagram of proposed system

A. On-off keying

It is the simplest form of amplitude shift keying(ASK) modulation scheme in which digital data is represented at the presence or absence of a carrier wave. Presence of a carrier for a period represents a binary one whereas its absence indicates a binary zero. Since a series of logical ones and zeros are represented by simply switching on and off the carrier ,it is referred to as on-off keying. OOK is more spectrally efficient than frequency shift keying.

Mathematically we can represent it as a waveform consisting of a signal

$$S(t)=a\sin\{2\pi ft+\phi\} \quad (7)$$

Where we set a=A, $\phi = 0$ when the bit is '1'and a = 0,$\phi = 0$ when it is '0'

On-off keying have been primarly adopted by optical communication systems that conveys information in the intensity,in either NRZ (non- return- to- zero) or RZ (return-to -zero) format. The advantage of OOK modulation is that the transmitter goes to 'idle' state during transmission of logic 'zero' ,thereby help in conserving battery.

B. VLC channel model

The impulse-response of a VLC channel consists of line of- sight (LOS) and non-line-of-sight (NLOS) parts. In VLC systems, the NLOS part of the impulse response is due to reflections of the light from the walls and other objects and usually causes inter-symbol interference at symbol-rates higher than 50 Msps. Given the sampling period, which is assumed to be the same as the length of the time-slots in this work, an equivalent discrete impulse response of the VLC channel, $\alpha = \alpha_l$, can be calculated from the continuous impulse-response. In the model the noise in the system is modelled as an additive white Gaussian noise (AWGN) source, which is a good approximation for high background light scenarios. The front-end of our VLC system model is depicted in Fig.4

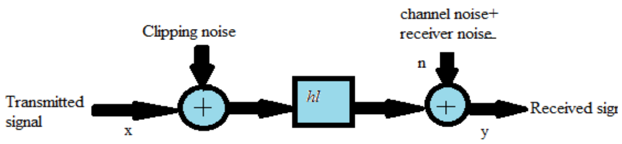

Fig.4 VLC system front end

C. Integrate and dump

The integrate and Dump block creates a cumulative sum of the discrete time input signal ,while resetting the sum to zero according to a fixed schedule. The input parameters for the process are the signal to be integrated along with the number of samples taken.ie the signal is integrated for one symbol period and its averaged value is stored to a variable. The process continues for the no of samples taken.

Receiver models often use integrate and dump operation when the system's transmitter uses a square pulse input. This operation is also used in fibre optics and in spread spectrum communication (CDMA).The block accepts a scalar, matrix input signal or a column vector. When the intermediate output values are cleared ,the output of the block gets delayed relative to its input throughout simulation. However the integrate and dump receiver inherently rejects all intersymbol interference due to the integrator resetting between bits.

In this method we specify the integration period in samples as a positive ,integer scalar greater than one. The integration period defines the length of the sample blocks that is integrated between resets. In digital communication the Integrate and dump filter is used as a matched filter for the detection of signals under additive white guassian noise (AWGN). The digital implementation of the IDF requires the input waveform to be sampled. This requires that the input signal be filtered first and then sampled to avoid aliasing.

D. Thresholding

The output of the integrate and dump block is subjected to thresholding to retrieve the demodulated signal. We find the maximum of the signal output of integrate and dump block. Then we find a signal 'x' such that

$$x= y/\max(y) \quad (8)$$

where y is the output of integrate and dump block. This signal is compared against a fixed threshold of 0.1 and the decision is made as follows

$$x <= 0.1 \text{ means logic } 0$$

$$x > 0.1 \text{ means logic } 1$$

Thus the demodulated signal is recovered at the receiver.

This data is compared to the transmitted data for analyzing error and various performance parameters are calculated namely bit error rate , energy efficiency.

IV. RESULTS AND DISCUSSION

We analyse the relation between bit error rate and average optical power.

Bit error rate of M-PAM HCM is calculated using the theorectical formula given by,

$$BER_{HCM} = \frac{M}{M-1} Q\left(\sqrt{\frac{3P^2/N}{\gamma(M^2-1)\sigma_N^2 + \sigma_{clip}^2}}\right) \quad (9)$$

where Υ represents the penalty in SNR due to pulse shaping, σ_N^2 is the variance of the additive guassian noise at the receiver , σ_{clip}^2 is the variance of the clipping noise, N is the order of hadamard transform and P is the power . Performance for different values of M and noise variance is also plotted.

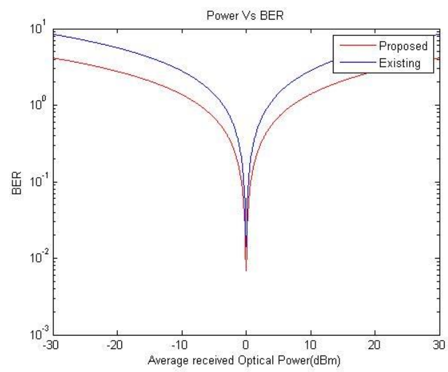

Fig 5.1 Power Vs BER for M=2

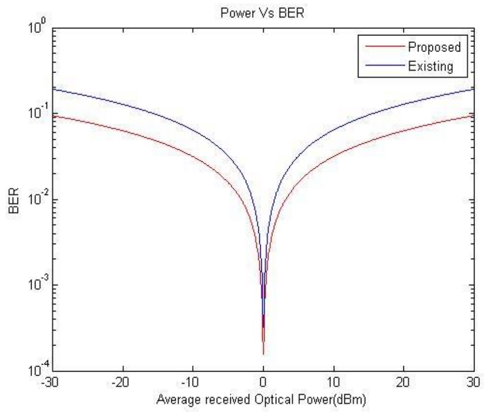

Fig 5.2 Power Vs BER for M= 8

For average powers less than P_{max} /2 ,the signals are not clipped by LEDs and the clipping noise is zero.ie $\sigma_{clip}^2 = 0$. For average powers larger than P_{max} /2 , σ_{clip}^2 comes into effect and is calculated using the formula

$$\sigma_{clip}^2 = \left(\frac{1}{2}\right)^N \sum_{k=N\frac{P_{max}}{P}}^{N} \left(k\frac{P}{N} - P_{max}\right)^2 \binom{N}{k} \qquad (10)$$

4.2

And hence after 0 dBm due to the clipping noise the BER further increases upto peak power limit.Beyond that both the existing and modified system also suffer clipping [9].

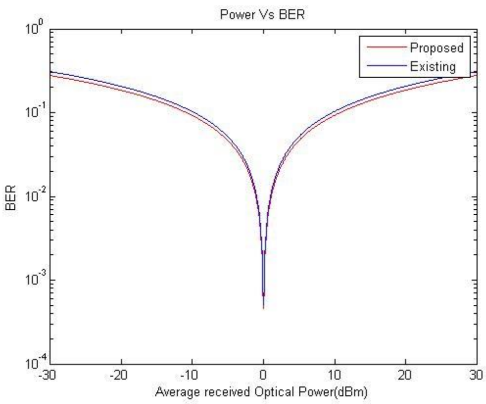

Fig 5.3 Power Vs BER for M= 16

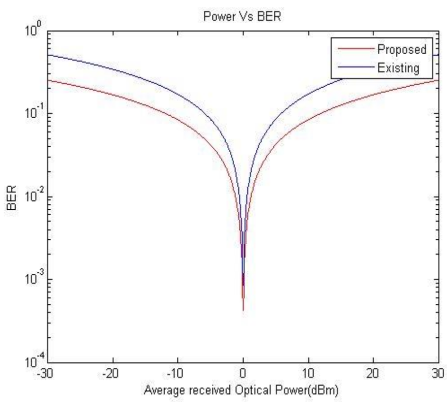

Fig 5.4 Power Vs BER for M= 32

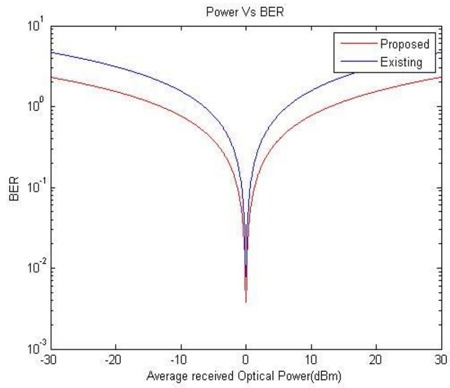

Fig 5.5 Power Vs BER for M= 512

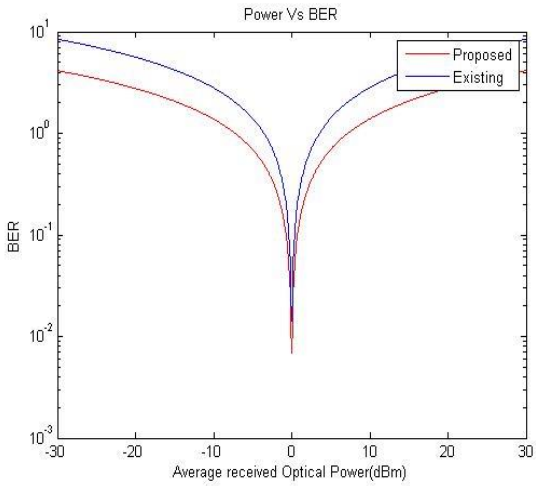

Fig 5.6 Power Vs BER for M= 1024

From the figures it is clear that lower order modulation gives better bit error rate. For high values of 'M',the bit error rate of the system also gets worse. Lower order modulations are more robust to noise than higher orders.

The energy efficiency of the system denoted as 'η' is given by the equation,

$$\eta = \frac{E\{x_n\}}{E\{x_n\} - E\{\min x_n\}} \qquad (11)$$

4.2

we assume the fact that all components of x_n are of equal mean ie $E\{x_n\}$ is fixed for all values of n= 0,1,…N-1.

Fig 5.7 shows the plot between energy efficiency in dB and order of hadamard transform $\log_2 N$. The graph is strictly linear which implies that as the order of the hadamard transform increases energy efficiency of the system also increase proportionately.

Existing system achieves a maximum of 32 dB whereas the proposed method improves it to around 48 dB with an improvement of 16 dB approximately.

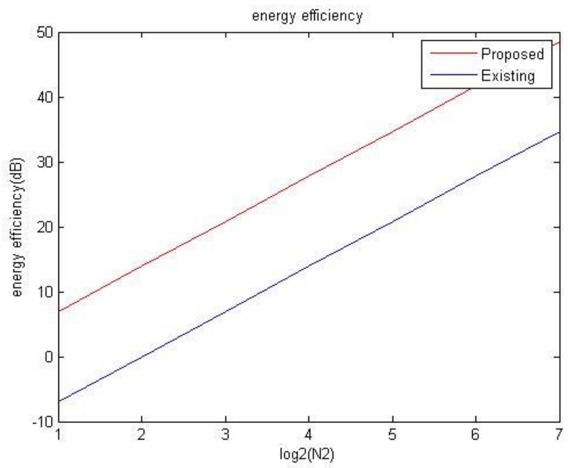

Fig 5.7 Energy efficiency Vs order of the hadamard transform

V. CONCLUSION

HCM was introduced as an alternative technique to OFDM for application in 1) optical wireless communications requiring high average power levels, such as VLC systems, and 2) systems with unconstrained average-power. The existing HCM system is modified to provide a better performance. On-off keying is used and the received signal is processed using integrate and dump,along with a fixed threshold to retrieve the transmitted signal. Both the existing and modified systems were implemented in MATLAB and various performance parameter graphs were compared.

The parameters of interest were bit error rate (BER) , Energy efficiency.Energy efficiency is plotted against order of hadamard transform and it was seen that energy efficiency of the system improves by 16 dB with the graph obeying a strictly linear characteristics. The bit error rate and the received power characteristics also show a slight improvement with a gradual breakdown at 0 dBm .

REFERENCES

[1] Mohammed Noshad and Maite Brandt-Pearce ,"Hadamard-Coded Modulation for Visible Light Communications''*IEEE Transactions on Communications*,vol. 64, no. 3, pp. 1167–1175(2016)

[2] K. J. Horadam ,Hadamard Matrices and Their Applications. Princeton University n Press,2006..

[3] J. Armstrong ,OFDM for optical communications, *J. Lightw. Technol.*,vol. 27, no.3 pp. 189–204(2009).

[4] S. Wang, S. Zhu, and G. Zhang , A Walsh-Hadamard coded spectral efficient full frequency diversity OFDM system, *IEEE Trans. Commun.*, vol. 58, no. 1, pp. 28–34(2010).

[5] M. Noshad and M. Brandt-Pearce , "Hadamard coded modulation: An alternative to OFDM for wireless optical communications," in *Proc. IEEE Global Commun. Conf. (GLOBECOM)*, Austin, TX, USA, pp. 2102–2107(2014).

[6] Z. Wang, Q. Wang, S. Chen, and L. Hanzo , "An adaptive scaling and biasing scheme for OFDM-based visible light communication systems," *Opt. Express*, vol. 22, no. 10, pp. 12707–12715(2014).

[7] Y.-P. Lin and S.-M. Phoong , "BER minimized OFDM systems with channel independent precoders," *IEEE Trans. Signal Process.*, vol. 51, no. 9,pp. 2369–2380(2003).

[8] S. Dissanayake and J. Armstrong , "Comparison of ACO-OFDM, DCO-OFDM and ADO-OFDM in IM/DD systems", *J. Lightw. Technol.*, vol. 31, no. 7, pp. 1063–1072(2013).

[9] Z. Wang, Q. Wang, S. Chen, and L. Hanzo , "An adaptive scaling and biasing scheme for OFDM-based visible light communication systems," *Opt. Express*, vol. 22, no. 10, pp. 12707–12715(2014).

[10] Sukhvir Singh,Gholamreza Kakamanshadi,and Savita Gupta, "Visible light communication-An emerging wireless communication technology",Proceedings of 2015 RAECS UIET punjab university(2015)