Hadamard Coded Modulation for Wavelet based Radio over Fiber Networks

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Abstract- With the advancements in the technology of communication, there has been an increase in demand of higher data rates for the services such as voice, multimedia and data over both wired and wireless links. Therefore there is the requirement of new modulation schemes to transfer the large amount of data that existing techniques may not be capable of supporting in future. OFDM so far has resulted in good performance on the implementation level but, the current competitive scenario require high data speed with minimum bit error rate and minimum delay. In this paper, PAPR, CCDF of OFDM is implemented using wavelet transform based Hadamard Coded Modulation (HCM) and discusses relationship between them for RoF networks. This paper also presents comparison of OFDM and DWT-HCM BER performance for different SNR values.

Keywords- *Bit Error Rate, Hadamard Coded Modulation, Walsh Hadamard Transform, Wavelet transform, Orthogonal Frequency Division Multiplexing, inter-symbol-interference, cyclic prefix, Cumulative Distribution Function, Probability Distribution Function, Peak To Average Power Ratio.*

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I. Introduction

In wireless communication today, there has been a variety of upgrades in wireless technologies and these technologies are vastly commercialised. Also, with time, these services have become popular and more demanding. Therefore, IEEE has standardized a number of wireless and wired services. OFDM is a part of these standards. It has been standardized for both types of communications. Apart from it, this paper discusses Hadamard Coded Modulation as one of the new techniques possible to be used for communication. The whole bandwidth in single carrier systems is dedicated to one symbol and these symbols are transmitted serially with time [1]. Since the channel is single, the signal is very difficult to recover, if the channel suffers variations. This requires some time consuming and complicated equalizers for reception. If the signal is transmitted over multiple channels which have different characteristics, the effect of channel variation can be minimized as the channel will offer different fading to different sub-channel channel. Those channels which experience more fading can be equalized by using equalisation techniques. This is the basic concept of different communication techniques and OFDM is one of the best standardized techniques [2].

The current study indicates that the network speed that presently is supported is increasing exponentially. Except for the voice rate, the demand for higher user end date rate whether it is wired or wireless communication. This leads to the need for some new formulation or modification in the existing techniques. This paper considers the OFDM performance issues and proposes Hadamard coded modulation for the different communication system more specifically here, for optical link communication. OFDM has found many application covering different areas such as mobile communication, direct television broadcasting ,for wireless networking and some private networks providing enough high data rates.

Orthogonal Frequency Division Multiplexing (OFDM) has been a digital transmission Method developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments but the increasing demand suggests that this is not going to be enough in coming years. OFDM is described as a robust technique that can be implemented in different environment conditions. The OFDM is a multi-carrier technique that provides it a capability to handle various frequency selective problems as an equivalent flat fading. Beside this, it gets affected by ICI by to frequency offset error [4]. Orthogonal frequency division multiplexing (OFDM) has been widely used for wireless communications. OFDM actually employ Fourier transform. The use of FFT technique to implement modulation and demodulation functions makes it computationally efficient in frequency domain. FFT is a lossless complex transform that modulate signal into real and complex entities. It can be understood that the real entity so far seems to be good enough for transmission but the imaginery entity can be ignored. Thus, OFDM has some part of data that is redundant. Hadamard transform is a transform that is different from FFT. It deals in binary simplifications which results in more efficiency. The sub division of the whole bandwidth results in efficiency and minimization of ICI noise. Further minimization of ICI in OFDM is done by use of Cyclic Prefix. The cyclic prefix is very effective to compensate for frequency selective channel fading. The use of cyclic prefix in MIMO-OFDM give much better results as the transmission is done through parallel flat fading sub channels rather than frequency selective channels, with proper use of cyclic prefix (CP). The Hadamard Coded Modulation does not require any Cyclic Prefix to be transmitted with symbols. However, frequency-selective fading effect in OFDM is difficult to eliminate completely, and inter carrier interference (ICI) and inter symbol interference (ISI) will be introduced. That is why Equalization techniques are important in MIMO-OFDM systems [5]. Synchronization, Inter-Carrier Interference and PAPR are the concerned problems in OFDM systems and many a research has been initiated. Some of the publications of late 1990s and 2000s indicate the analysis and solution of the problems. This paper discusses the overview of OFDM in section I and different OFDM parameters in section II and section III, IV and V discusses the proposed DWT-HCM.

II. Characteristics of OFDM

PAPR is an important parameter to describe the performance in communication systems. The PAPR of the OFDM signal can be written as peak power with respect to the average power[6].

$$PAPR\{s(t),\tau\} = \frac{\max_{t\in\tau}[s(t)]^2}{E\{[s(t)]^2\}} \quad .....(1)$$

where, s(t) is the original signal, τ is the time interval $\max_{t\in\tau}[s(t)]^2$ is the peak signal power, $E\{[s(t)]^2\}$ is the average signal power.

However, it is seen that the occurrence probability of the peak signals is very low, thus it is actually not meaningful to use $\max_{t\in\tau}[s(t)]^2$ for peak value. Therefore, PAPR performance of OFDM signals is commonly measured by certain characterization constants which are related to probability.

a) Probability Distribution Function of PAPR

According to central limit theorem, the mean of large number of multi-carriers signal, will obey Gaussian distribution which have mean value of 0 and variance of 0.5. F(p) denoting the Cumulative Distribution Function (CDF) is as follows [7]:

$$F(p) = (1-\exp(-p)) \quad .....(2)$$

The probability distribution function for PAPR less than a certain threshold value (p), can be written as PAPR

$$P\,(PAPR < p) = F\,(p)^N = (1-\exp(-p))^N \quad ....(3)$$

Where N comprises the number of subcarriers and F(p) is the Probability Distribution Function for PAPR.

b) Classification of Existing Techniques

There have been various techniques proposed for minimization of PAPR which can be categorized as follows [8]:

- Signal Scrambling
- Signal Distortion

Scrambling category works well only with side information .this is because it use a variety of codes that provide redundancy. Few examples of thesuch coding forms are Barker codes, M-sequences, Golay complementary and Shapiro-Rudin sequences. The only disadvantage it has is that it increases the overhead exponentially as the number of carriers increase. Among these, selective mapping, partial transmit sequences and block coding are better techniques. The scrambling category can be classified as follows [9]:

- Schemes that uses side information
  - (a) Block codes: it consists of linear block code scheme, cyclic code scheme.
  - (b) Probabilistic schemes: e.g. SLM scheme, PTS scheme, Interleaving schemes.
- Schemes which do not use explicit side information. Such schemes are Special Block coding scheme, Hadamard transform method, Dummy sequence insertion method etc.

Signal scrambling techniques divides the long sequence of information into small blocks and some redundancy bits are added to each block. This acts as side information but, reduces the OFDM throughput. The signal distortion techniques introduce both in-band and out-of-band interference and complexity to the system, whereas the distortion category techniques enhance PAPR reduction by modification of signal before amplification. Clipping is helpful in removing expanded signal after amplification but it can cause some peak regrowth and increase in both out-of-band (OOB). Any technique used for the reduction of PAPR should not only have high spectral efficiency but must be compatible with the existing modulation schemes and at the same time must not be computational complex. [8]

III. Proposed Scheme

The transmitter and the reciever for the HCM technique is shown below:

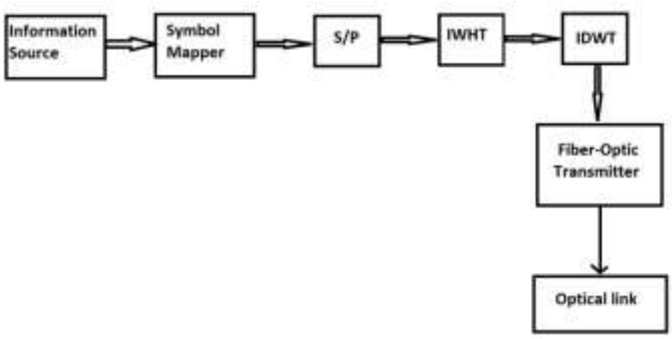

Fig 1: HCM transmitter

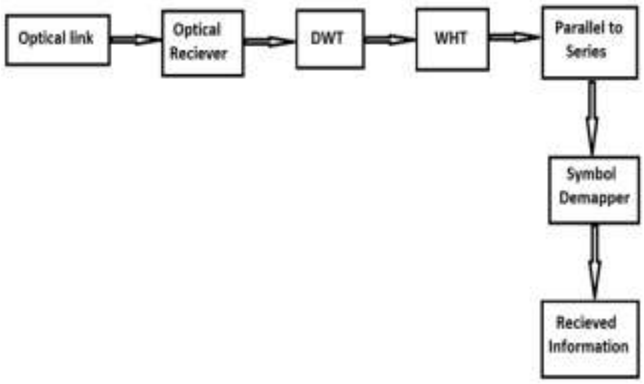

Fig 2: HCM Reciever

The proposed system is based on the Walsh-Hadamard-Wavelet Transform which combines all the sub-carriers available in the channel into various Frequency level and then combines the total signal values into a single frequency space, the wavelet has the advantage of reduced inter channel interference as the combination of the different users is better matched with Wavelets with reduced cyclic errors and moreover the hadamard increases the security by a secondary dictionary coding ensuring low inter symbol interference in more bottlenecked usage. The error generated by the AWGN channel in OFC is also simulated.

The proposed system is implemented using Inverse Hadamard Transform followed by Inverse Discrete wavelet coding at the transmitter for modulating data. A simulation based trans-reciever system is formulated. The reciever system is implemented using forward hadamard transform followed by forward Discrete Wavelet transform coding. The PAPR values are obtained for the whole communication system and the change in overall BER is calculated.

IV. Radio over Fiber networks

Due to too much use of RF spectrum the use of bandwidth for new broadband service turning to be more difficult. Optical wireless networking utilizes a very wide unoccupied bandwidth that can be exploited for communication for small distance connectivity eg., in indoor environment or local area network to utilize high speed multimedia services. For such applications, the optical signal offers greater propagation immunity and secure at the physical layer. At the same time, optical wireless networking systems offer user mobility and are robust in the presence of shadowing but they can be significantly weakened by multipath propagation which results in serious interferences. Wavelength diversity can be employed by reuse of wavelengths in other parts of an organization using Wimax like concept [10].

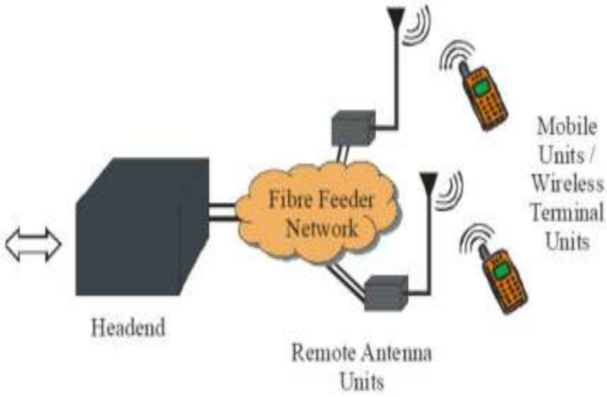

Fig 3: The Radio over Fiber System

V. Hadamard Transform

Use of Hadamard transform is a cost effective due to its less hardware complexity. OFDM which has been proved to be a promising technique for optical communication poses a challenge to implement the IFFT and FFT. Therefore using Hadamard shrinks the structure complexity. Since the Hadamard transform matrix consists of only of +1 and −1 entries, there is no need of complex multiplicative calculations [11].

A Generalised Hadamard Transform (GHT) of x is

$$\hat{y} = Hx \quad .....(4)$$

and an Inverse Hadamard Transform (IGHT) of ŷ is

$$x = n^{-1}H^{*}\,\hat{y} \quad .....(5)$$

Recursively, we define the 1 × 1 Hadamard transform H_0 by the identity $H_0 = 1$, and then define H_m for m > 0 by:

$$H_m = \frac{1}{\sqrt{2}}\begin{bmatrix} H_{m-1} & H_{m-1} \\ H_{m-1} & -H_{m-1} \end{bmatrix} = H_1\,\Theta H_{m-1} \quad ....(6)$$

where, ϴ represents the Kronecker product of two matrices. This technique can be successfully combined with the Wavelet Transform to give better results.

Assuming the noise due to channel to be Gaussian (AWGN) which has a characteristics for the output to be $y = h_* x + n$, the BER of M-PAM HCM can be calculated from as

$$BER_{HCM} = \frac{M-1}{M\log_2 M}\,Q\left(\sqrt{\frac{3}{M^2-1}}\,\frac{\sigma}{\sigma_n}\right) \quad .....(7)$$

The optical average power is equal to σ, where σ is the electrical HCM signal power and Q represents the Gaussian function. The Bit error rate of HCM varies at different values of SNR (E_b/N_o) [12].

For average power levels less than $P_0/2$, the HCM signals are not distorted by the LED nonlinearity and the performance of HCM is only limited by the noise.

VI. Wavelet Division Multiplexing

Wavelet division multiplexing is based on Wavelet Transform. It is the merging of message in coded form over the wavelet function before transmission. It leads to an

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increase of symbol duration [13]. It reduces the importance of guard interval largely, instead, it uses number of the wavelet packet signals. The efficiency of wavelet packets is 30% more than the conventional frequency division multiplexing in the occupied frequency band. Wavelet packets generate strong orthogonality that allows overlapping of frequency with complete seperability. Whereas, the frequency division require about 30% channel for the guard bands in a particular channel. Corresponding to Wavelet Division Multiplexing the Wavelet Transform is given as:

The wavelet transform corresponds to the decomposition of a quadratic integrable function s(x) is a function of $L^2(R)$ in a family of scaled and translated functions $¥_{k,l}(t)$,[14]

$$¥_{k,l}\,(t) = k^{-1/2}\, ¥(\frac{t-l}{k}) \qquad .....(8)$$

The function ¥ (x) is described as wavelet function and shows band-pass behaviour. The wavelet coefficients $d_{k,l}$ are derived as follows

$$d_{k,l} = \frac{1}{\sqrt{2}}\int_{-\infty}^{\infty} s(x)\, ¥^{*}\, (\frac{x-l}{k})dx \qquad ….(9)$$

where $k \in R$, $l \in R$ and * denotes the complex conjugate function.

VII. Results and Discussions

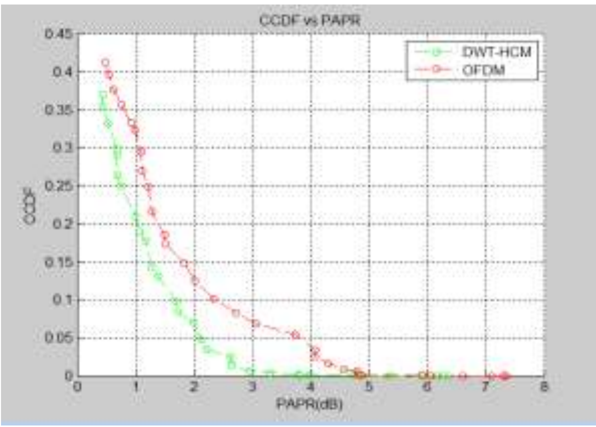

Figure 4: PAPR to CCDF distribution for the OFDM and DWT-HCM Transform modulation.

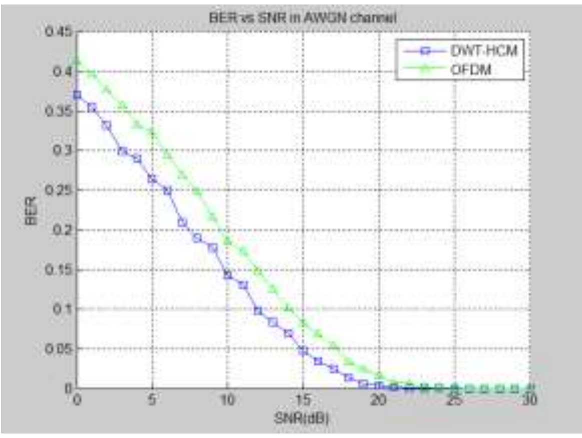

Fig 5: SNR ratio to BER distribution for the OFDM and DWT-HCM Transform modulation

The above results are carried out using equation (1), (2),(7),(8) and (9) for a 4 channel network, 256 QPSK modulation having 4 subcarriers with gain values from 0 to 30db under AWGN channel tuned according to OFC noise assessment.

VIII. Conclusion

The DWT-HCM achieves a lower error probability or PAPR. Moreover, it does not require signal clipping or dc bias reduction because Hadamard transform modulation results in low signal amplitudes. The results for bit error are shown to have reduced values as compared to OFDM because of the fact that the sources of error in optical fiber are due to the intrinsic distortions, noise of semiconductor lasers together with the partition noise, but are very minimal. This makes the BER performance directly dependent over PAPR performance. Thus DWT-HCM is better suited for Fiber networks employing higher frequencies. The simulation results for capacity of DWT-HCM shows that its capacity as compared to OFDM is always more for different SNR values. Since, it has to be used for the optical fiber. The spectral efficiency of the optical fiber is quite large upto 100GB/s per channels. Therefore, it is possible to employ complete spectrum of optical fiber in order to manage large-bandwidth signals without disturbing or interfering the low-frequency wireless channels. DWT generate various frequency bands which result in high signal correlation making it compatible for multi-mode fiber transmission. Practically, it is not possible to cover whole of the bandwidth that optical fiber supports but this gives DWT-HCM a good chance to be able to upgrade the capacity further more.

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