

Introduction of Hadamard Coded Modulation For Optical fiber communications systems

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Abstract- Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique against the multipath fading channel for wireless communications. OFDM is a multiplexing technique that is useful in wireless transmission of data. OFDM system is use for high speed applications. The OFDM-related technique has been invented over 40 years ago, but it has gone through many advancements over the years . OFDM for wireless communications has intensively been an active research area in the past 10 years. Hadamard transform modulation is also one of the latest approach for modifications in the OFDM to bring some advantage to it. Due to its various advantages, the HCM can be used in optical fibre applications, Radio Over fiber is one of it. In this paper, HCM and its use in OFDM has been discussed for the application of Rof.

Keywords- Orthogonal Frequency Division Multiplexing (OFDM),Hadamard Coded modulation (HCM), BER , PAPR , IEEE, Radio Over Fiber(Rof), Channel Capacity.

I. Introduction

The ever increasing demand for very high rate wireless data transmission calls for technologies which make use of the available electromagnetic resource in the most intelligent way. Key objectives are spectrum efficiency (bits per second per Hertz), robustness against multipath propagation, range, power consumption and implementation complexity. These objectives are often conflicting, so techniques and implementations are sought which offer the best possible trade off between them [1]. The Internet revolution has made the requirement for wireless innovations that can convey information at high speeds in a spectrally productive way. In any case, supporting such high data rates with sufficient robustness to radio channel impairments requires cautious determination of modulation techniques. Presently, the most suitable choice appears to be OFDM (Orthogonal Frequency Division Multiplexing). One of the primary motivations to utilize OFDM is to build the vigor against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small

percentage of the subcarriers will be affected. Error correction coding can then be used to correct for the few erroneous subcarriers. The concept of using parallel data transmission and frequency division multiplexing was published in the mid-1960s.

OFDM is a special case of multi-carrier modulation, where as Multi-carrier modulation is the concept of splitting a signal into a number of signals, modulating each of these new signals to several frequency channels, and combining the data received on the multiple channels at the receiver [2]. In OFDM, the multiple frequency channels, known as sub-carriers, are orthogonal to each other [3].

II. OFDM

At present, wireless communication systems are facing problems mainly multi-path fading, frequency fading, Inter Symbol Interference (ISI), Inter Carrier Interference (ICI), lower bit rate capacity , requirement of larger transmit power for high bit rate, less spectral efficiency etc. OFDM is type of MCM technique which is suitable choice for full capacity wireless networks [4]. OFDM is effective technique for high data rate wireless communication in multi-path channels and fading environment at reasonable complexity in wireless

channels. Because of its high speed data transmission and effectiveness in combating the frequency selective fading channel, it is adopted by many standards DAB, ADSL, WLAN, IEEE 802.11 a/g/n etc [5, [6]. Error control codes have become a vital part of modern digital wireless system; enabling reliable transmission to be achieved over noisy channels OFDM which is suitable for high data rate transmission is combined with FEC methods called Coded OFDM (COFDM) which enables the OFDM system to enhance the system throughput. In Wireless communication systems main challenge is to provide high data rate environment and reliable transmission so channel coding scheme is essential for improving reliability of transmission. COFDM is more immune to impulse noise, random noise, multi-path distortion, fading and interference. COFDM provides high spectral efficiency and reliable transmission by spacing channels close together.

The OFDM signal generated by the system in Figure 1 & 2 is at baseband; in order to generate a radio frequency (RF) signal at the desired transmit frequency filtering and mixing is required. OFDM allows for a high spectral efficiency as the carrier power and modulation scheme can be individually controlled for each carrier. However in broadcast systems these are fixed due to the one-way communication. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers.

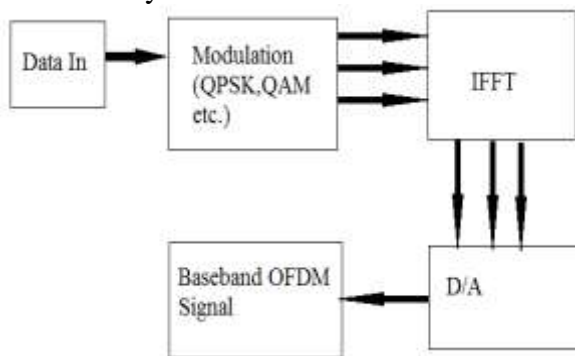


Fig. 1: OFDM Transmitter

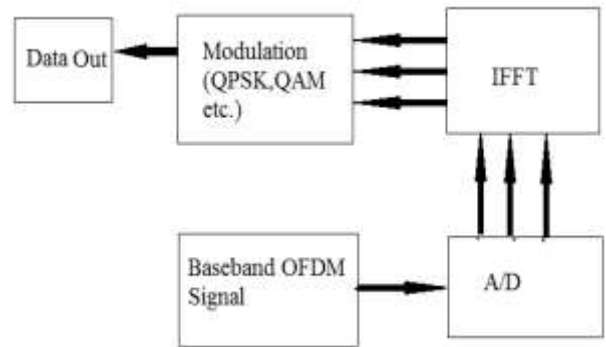


Fig.2: OFDM Receiver

III. Principle of OFDM

In digital communications, information is expressed in the form of bits. The term symbol refers to a collection, in various sizes, of bits [12]. OFDM data are generated by taking symbols in the spectral space using M-PSK, QAM, etc, and convert the spectra to time domain by taking the Inverse Discrete Fourier Transform (IDFT). Since Inverse Fast Fourier Transform (IFFT) is more cost effective to implement, it is usually used instead [13]. The primary highlights of a practical OFDM framework are as per the following given in [13]:

- Some handling is done on the source information, such as coding for correcting errors, interleaving and mapping of bits onto symbols. A case of mapping used is QAM.
- The symbols are modulated onto orthogonal sub-carriers. This is done by utilizing IFFT.
- Orthogonality is kept up amid channel transmission. This can be attained to by adding a cyclic prefix to the OFDM frame to be sent. The cyclic prefix comprises of the last few samples of the frame, which are replicated and placed in the beginning of the frame. It must be longer than the channel impulse response.
- Synchronization: cyclic prefix can be utilized to distinguish the begin of each frame. This is done by utilizing the way that the few first and last samples are the same and subsequently correlated.
- Demodulation of the received signal by using FFT.
- Channel equalization: the channel can be assessed either by utilizing a training sequence or sending known so-called pilot symbols at predefined sub-carriers.
- Decoding and de-interleaving.

IV. CODED OFDM

The efficiency of OFDM can be enhanced by various methods and the best performance is provided by this technique than other in fading environment. [7]. A robust data transmission can be achieved by combining OFDM with channel coding called COFDM [8]. A promising candidate that provides a means to transmit data in a frequency selective channel is COFDM. This technique uses multiple orthogonal sub-carriers to convey the data and error correcting code which adds extra bits at transmitters to recover many or all the sub-carriers affected by deep fades. The error correcting code usually adopted to improve OFDM system performance in adverse channel condition is FEC [9].

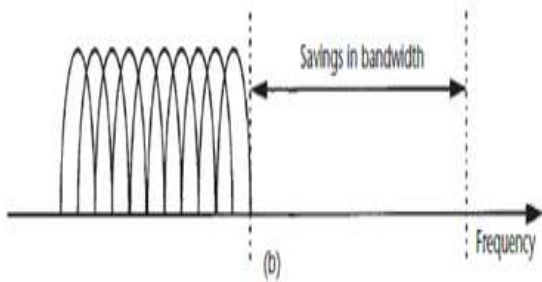


Fig. 3: COFDM Signal

By using the overlapping multi-carrier modulation technique, save almost 50% of bandwidth as shown in Fig. 3. Transmission quality can be further improved by combining FEC and interleaving that overcomes the effect of burst errors and fading type errors [9]. OFDM is combined with channel coding by which error of weak sub-carrier is corrected by the information of strong sub-carriers is corrected by the information of strong sub-carriers; thereby the total error rate is decreased. If channel coding is not used system efficiency is limited to the power of weakest sub-carriers [10].

V. Hadamard Coded Modulation

Hadamard Coded Modulation is one of the coding based technique has been introduced in [10] which uses Fast Hadamard Transform to modulate data. It has been described as a technique alternative to OFDM and has shown better performance for high average optical power scenerios with very small PAPR and can be used instead of OFDM in following two scenerios

- 1) In Visible Light Communications
- 2) In optical wireless communications

Hadamard transform is a good tool used for modulation instead of precoding. It has been shown that a PAPR of 2 can be achieved using HCM which is significantly lower than OFDM.

BER for HCM is given as

$$BER_{OFDM} = \frac{2(\sqrt{M} - 1)}{\sqrt{M} \log_2 M} Q \left(\sqrt{\frac{3SNR}{M - 1}} \right)$$

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

VI. Hadamard Codes :

Hadamard codes considered to be analogous to the Walsh sequences or the first-order Reed–Muller codes up to interleaving , have been used widely in communication systems for synchronization and bandwidth spreading. However, Hadamard codes provides the coding gain which is relatively low, e.g., a length- bi-orthogonal but Hadamard code can achieve BER at 4 dB, about 6 dB away from the ultimate Shannon limit. The Hadamard Transform requires additions using a straight forward implementation. This cost can be greatly reduced by the Fast Hadamard Transform (FHT) technique[12].

VII. Radio-over-Fiber Technology:

The next-generation access networks are driving the needs for the convergence of wired and wireless services for high-speed, symmetric, and guaranteed bandwidth demands.[11]. One such technology is Radio-over-Fiber Technology. This technology is the integration of microwave and optical networks which is a possible solution for the increasing capacity and mobility as well as decreasing costs in the access network[11]

VIII. Channel Capacity:

There is, to determine the following basic requirement that upto what maximal error-free data rate can be expected from a fiber optic medium? While Shannon's results address this question in a general sense, with the exception of the additive white Gaussian noise (AWGN) model, computing the theoretical information capacity has proved to be mathematically challenging for many channels. The fiber

nonlinearities in WDM networks allow for coupling amongst channels, giving rise to undesired effects such as stimulated Raman scattering (SRS), cross-phase modulation (XPM), and four-wave mixing (FWM)[13]. Any attempt to derive the information capacity of the highly nonlinear WDM channel based on the AWGN assumption will evidently yield inaccurate results. The right approach is to obtain a model that takes into account the physical properties of the fiber optic which has been discussed in [13]

IX. Limitations of OFDM:

There are some obstacles in using OFDM which are as given in [1]:

- OFDM signal exhibits very high Peak to Average Power Ratio (PAPR).
- Very sensitive to frequency errors (Tx. & Rx. offset)
- Intercarrier Interference (ICI) between the subcarriers.

X. Conclusion

Orthogonal frequency division multiplexing (OFDM) is a widely used modulation and multiplexing technology, which has become the basis of many telecommunications standards including wireless local area networks (LANs), digital terrestrial television (DTT) and digital radio broadcasting in much of the world. In the past, as well as in the present, the OFDM is referred in the literature as Multi-carrier, Multi-tone and Fourier Transform. On the other hand, HCM has a low complexity and can exploit the bandwidth effectively. And is also able to achieve lower BER levels compared to OFDM. This paper has explored the role of OFDM as well as HCM in the optical communication. There are also some limitations of OFDM technique which can be removed with the help of suitable techniques such as HCM .

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