# Optical OFDM for Broadband Communication

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***Abstract****-Orthogonal frequency division multiplexing (OFDM) is a modulation technique which is now used in most emerging broadband wired and wireless communication systems because it is an effective solution for inter symbol interference caused by a dispersive channel. Recently a number of researchers have proved that OFDM is also a promising technology for optical communications. To achieve good performance in optical systems OFDM must be adapted in various ways. The constraints imposed by single mode optical fiber, multimode optical fiber and optical wireless are discussed and the new forms of optical OFDM which have been developed are outlined.*

***Keywords***-OFDM, ISI, DVB, DAB

## I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an attractive modulation format that recently received a lot of attention in the fiber-optic community [1]. The main advantage of optical OFDM is that it can cope with virtually unlimited amount of intersymbol interference (ISI). In high-speed optical transmission systems, chromatic dispersion and polarization mode dispersion (PMD) causes ISI, which are serious issues in long-haul systems whose bit rate is higher than 40 Gbit/s. The general block diagram of OFDM system is shown in Fig. 1.

Coming to the description of optical OFDM transmission, we will review some fundamental concepts and basic mathematic expressions of OFDM. It is well known that OFDM is a special class of multi-carrier modulation (MCM), a generic implementation. The key distinction of OFDM from general multicarrier transmission is the use of orthogonality between the individual subcarriers. Fig 2. Illustrate the OFDM for dispersion compensation for long haul system.

A serial-to-parallel converter (DEMUX) sends the information sequence into blocks of B bits. The frame in each block (B bits) are subdivided into K subgroups with the $i^{th}$ sub-group that contains bi bits, B=∑bi. Various modulation schemes could be employed such as BPSK, QPSK (also with their differential form) and QAM with several different signal constellations. The data symbols are parallelized in N different sub streams. Each sub stream will modulate a separate carrier through the IFFT modulation [2]. A cyclic prefix is inserted in

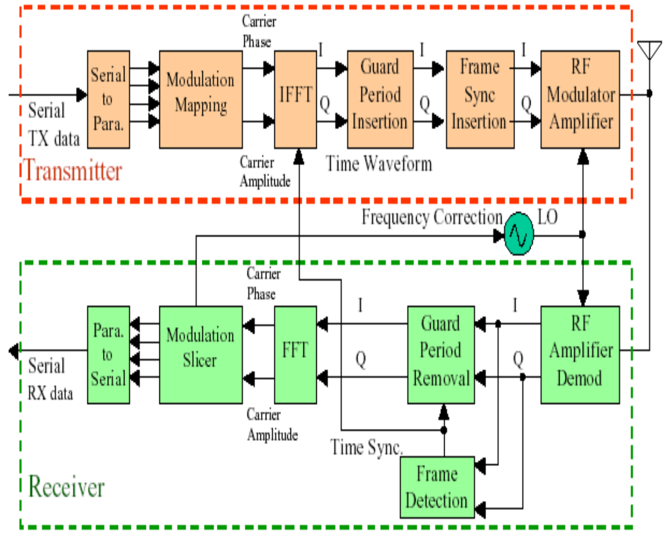



Fig. 1. General Block Diagram of OFDM System

order to eliminate the inter-symbol and inter-block interference (IBI) and inter carrier interference [3].The last L samples of the symbol are modulated along with the data streams. The data will be back-serial converted, which forms an OFDM symbol that modulates a high-frequency carrier before its transmission through the channel. Linear time-variant system is used to refer a radio channel. In the receiver, the inverse operations are performed. The data are down-converted to the baseband. Cyclic prefix is removed. The exact form of transmitted symbols is retrieved by the coherent FFT demodulator. The bi bits from the $i^{th}$ subgroup are mapped into a complex-valued signal point from a 2bi-point signal constellation such is, e.g., QAM [4]. It is the most conventional method used for bandwidth efficiency. The complex-valued signal points from all K sub-channels are considered as the values of the discrete Fourier transform (DFT) of a multicarrier OFDM signal. Therefore, the symbol interval length in an OFDM system is T=KTs, where Ts is the symbol-interval length in a single-carrier system. It is efficient than frequency division multiplexing[5].By selecting K, the number of sub-channels, sufficiently large, the OFDM symbol interval can be made much larger than the dispersed pulse-width in a single-carrier system, resulting in a small inters symbol interference.

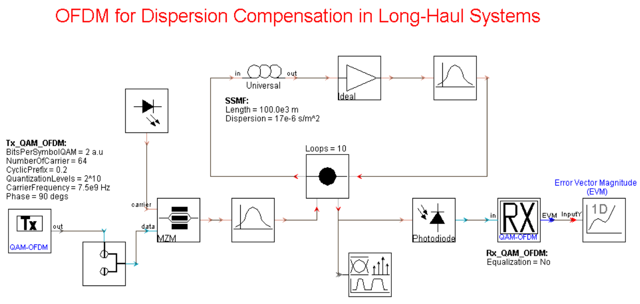



Fig. 2. OFDM for Dispersion Compensation

Higher spectral efficiency is achieved for larger number of users in a cell due to the multiuser diversity. There are various applications for OFDM standards. OFDM forms the basis for the Digital Audio Broadcasting (DAB) standard in the European market. Digital Audio Broadcasting (DAB) using OFDM has been standardized in Europe. It is considered as the next step in evolution beyond FM radio broadcasting, COFDM (coded OFDM) is used properly for TV broadcasting. It is feasible for single frequency networks[6].These are some of the examples for the links and cables like/T2 (terrestrial), DVB-H (handheld), DMB-T/H, DVB-C2 (cable), With the help of OFDM based wireless LAN, data rates up to 54Mbits/s can be transmitted with delay spread robustness that is efficient for most indoor wireless applications [7].

Some of the popular standards are IEEE 802.11a, IEEE 802.11g, IEEE 802.11n, IEEE 802.11ac and IEEE 802.11ad, WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communication technique dedicated for broadband wireless access (BWA) networks. Li-Fi.(Light Fidelity) in Orthogonal frequency-division multiplexing (OFDM) has been used for the intensity-modulated/direct-detection (IM/DD) optical channels to create high speed communication links, ADSL(G.dmt/ITU G.992.1) The LTE and LTE Advanced 4G mobile phone standards. Evolving technology use this technique to improve the capacity and for efficiency [8].

There are some obstacles in using OFDM which are as given: OFDM signal exhibits very high Peak to Average Power Ratio (PAPR). It is very sensitive to frequency errors (Tx. & Rx. offset) Inter carrier Interference (ICI) between the subcarriers.

## II. OPTICAL OFDM

The main features of a practical OFDM system are as follows: Some processing is done on the source data, such as coding for correcting errors, interleaving and mapping of bits onto symbols. An example of mapping used is QAM[17]. The symbols are modulated onto orthogonal sub-carriers. This is done by using IFFT.

### *A.* Orthogonality

It is maintained during channel transmission. This can be achieved by adding a cyclic prefix to the OFDM frame to be sent. The cyclic prefix consists of the L last samples of the

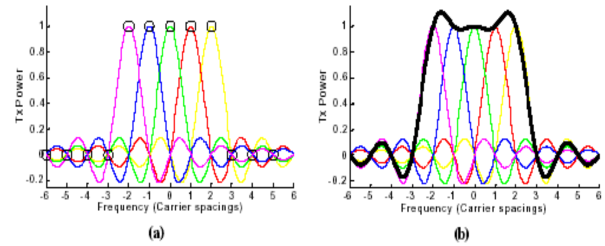
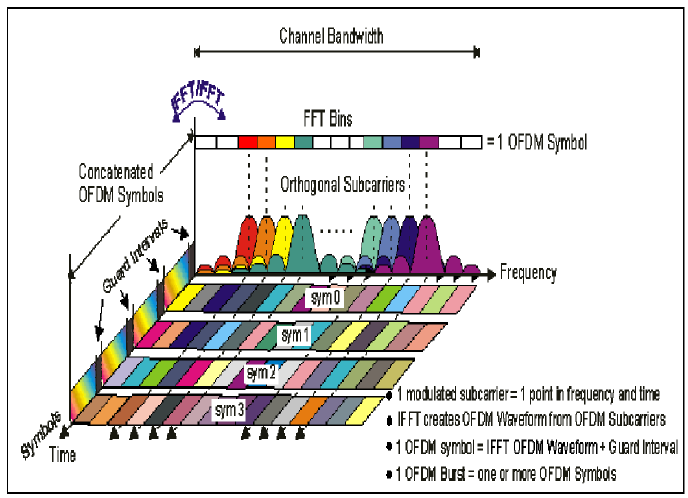



Fig 3.OFDM in Frequency Domain




**Frequency-Time Representative of an OFDM signal**

Fig 4. Frequency Time representation

frame, which are copied and placed in the beginning of the frame. It must be longer than the channel impulse response.

### *B.* Synchronization

Cyclic prefix can be used to detect the start of each frame. This is done by using the fact that the L first and last samples are the same and therefore correlated. Demodulation of the received signal is done by using FFT[18].

### *C.* Channelequalization

The channel can be estimated either by using a training sequence or sending known as pilot symbols at predefined sub-carrier signals by Decoding and de-interleaving.It is Performed in frequency domain and FFT is compulsorily performed in Receiver.

## III. ELIMINATION OF ISI

It is feasible to insert a guard interval between the OFDM symbols to eliminate the inter symbol interference. The guard interval also obliterates the need for a pulse-shaping filter, and the sensitivity to time synchronization problems is reduced in Fig3. In Fig.4, the cyclic prefix is transmitted during the guard interval along with the data symbols to provide synchronization between the symbols. It precedes the data thus the need for pilot symbols is reduced [4]. Fig 5.illustrates the cyclic prefix to maintain orthogonality.

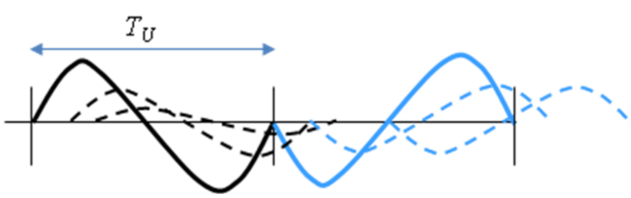



Fig 4.Intersymbol Interference in a Multipath Channel

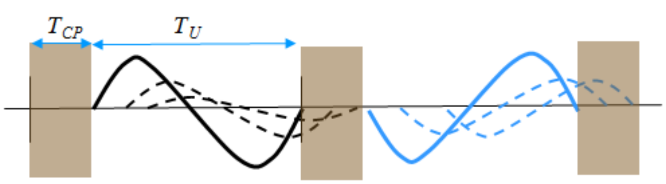



Fig. 5.Guard Interval with Cyclic Prefix

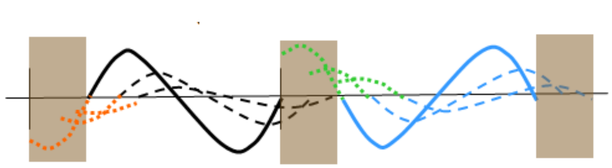


Fig. 6.Cyclic Prefix to maintain orthogonality

## IV. REAL-TIME COHERENT OPTICAL OFDM

The real-time optical OFDM has progressed rapidly in OFDM transmitter. OFDM receiver and OFDM transceiver. Importantly, OFDM is based on symbol and frame structure, such as window synchronization and channel estimation.

In addition, it is envisioned that aggregate rates of up to 40 Gbit/s and 10 Gbit/s downstream/upstream over up to 100 km reach would be offered by such systems link. OFDMA is a multi-user version of OFDM whereby instead of assigning all the subcarriers to one user, subsets of subcarriers are assigned to different users [12].

### A. Variants

There are three optical OFDMA variants. In the first variant, referred to as 1-D OFDMA, different subcarriers from the same OFDM band are assigned to different users. The second variant is called 2-D OFDMA, where different users are assigned different OFDM subcarriers and TDM time-slots. It is therefore a combination of 1-D OFDMA with TDMA. The final variant, called 3-D OFDMA features different users being assigned different OFDM subcarriers and TDM time slots on different WDM wavelengths. The dynamic bandwidth allocation, TDM slot scheduling, as well as the wavelength assignment can all be implemented in DSP.

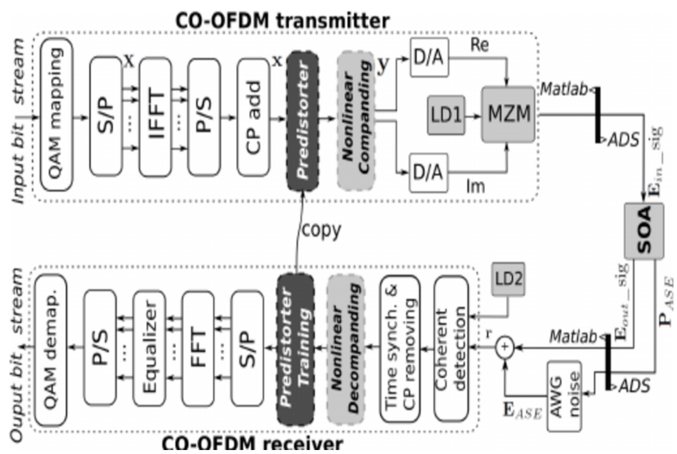



Fig 7. Coherent OFDM Transmitter and Receiver

## V. ADAPTIVELY MODULATED OPTICAL OFDM

Adaptively Modulated Optical OFDM Signals over Multimode Fibers is used for High-Speed Transmission Using Directly Modulated DFBs. Directly modulated distributed feedback (DFB) lasers are used in multimode fiber (MMF) based links directly. Various launching condition such as fiber types and modal dispersion when compared to other existing techniques is flexible. Adaptive modulated OFDM signals is viable for DML based links with 3-dB effective bandwidth and operational frequency of 200MHz.High spectral efficiency is achieved in this system [13].

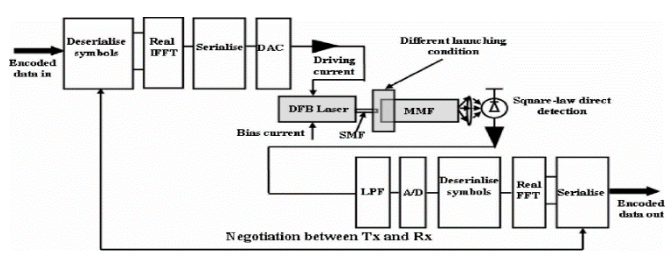



Fig 8: The transmission link diagram for adaptively modulated optical frequency and division multiplexing.

### A. MIMO-OFDM Systems

Energy efficiency is considered as one of the key parameter in the design and evaluation of mobile communication in addition to the quality of services (QOS) fig 8.shows the system representation of MIMO-OFDM. Channel characteristics classify all sub channels using singular value decomposition method. It is the generalization of the Eigen decomposition of a positive semi definite normal matrix. in order to improve the energy efficiency, a new algorithm is formed namely EEPOA(Energy Efficiency Optimized Power Allocation). This technique is used as a effective solution for the modification for multi channel joint optimization problems in conventional method over multi target single channel optimization [14]. It assures the QOS we require. Fig. 9. shows the MIMO-OFDM system model representation.

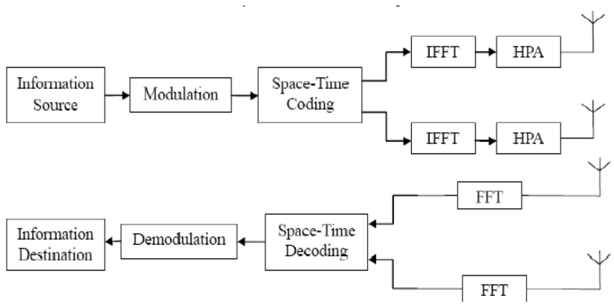



Fig 9: MIMO AND OFDM System Representation

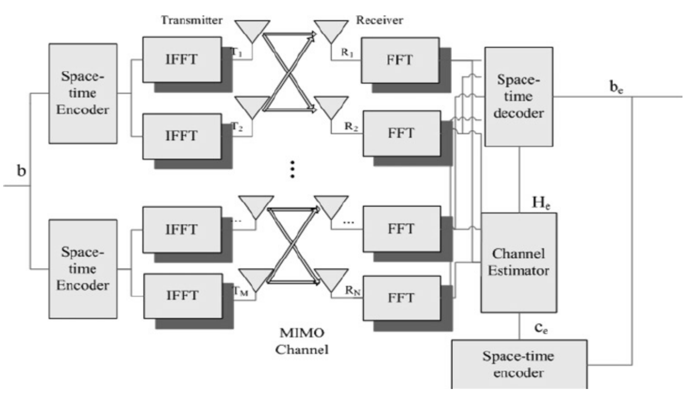



FIG 10.MIMO-OFDM System Model

## VI. ADVANTAGES OF OFDM

Advantages of optical OFDM are listed in this section.

- Immunity to selective fading

One of the main advantages of OFDM is that is more resistant to frequency selective fading than single carrier systems because it divides the overall channel into multiple narrowband signals that are affected individually as flat fading sub-channels.

- Resilience to interference

Interference that appears on a channel may be bandwidth limited and thus it will not affect all the sub-channels. This shows that not all the data is lost.

- Spectrum efficiency

Using close-spaced overlapping sub-carriers, a significant OFDM advantage is that it makes efficient use of the available spectrum.

- Resilient to ISI

One of the major advantages of OFDM is that it is very resilient to inter-symbol as well as inter-frame interference. This results from the low data rate on each of the sub-channels.

- Simpler channel equalization

One of the issues with CDMA systems was the complexity of the channel equalization which had to be applied across the whole channel. An advantage of OFDM is that using multiple sub-channels, the channel equalization becomes much simpler.

## VII. CONCLUSION

The demand for high data rate wireless communication has been increasing drastically over the last decade. One way to transmit this high data rate information is to employ well known conventional single carrier systems. Since the transmission bandwidth is much larger than the coherence bandwidth of the channel, highly complex equalizers are needed at the receiver for accurately recovering the transmitted information. Multi-carrier techniques can solve this problem significantly. In this paper we have discussed about the basic idea behind the OFDM, the most emerging technology of this era. Here we take a review on its concept, its properties in terms of its advantages and disadvantages, its limitations and also its applications in different fields. The role of OFDM in the wireless communication and its advantages over single carrier transmission is explained here. There are also some limitations of this technique which can be removed with the help of suitable techniques.

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