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# Design of Orthogonal Frequency Division Multiplexing based High Speed OFC System

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*Abstract*— **Fiber optic transmission can be employed in any situation where data must be transferred from one location to another. Glass fibers, on the other hand, are used in modern telecommunications infrastructure because of its increased capacity and low attenuation. Data rates of 100 Gbps and more are in high demand in the access, corporate, metropolitan, regional, and long-distance markets. As a result, next-generation transmission technologies are required; otherwise, the optical infrastructure would become overburdened and its existing capacity will be exceeded. Orthogonal frequency division multiplexing (OFDM) is thought to be a potential solution for meeting the growing demand for bandwidth in broadband services. Orthogonal frequency division multiplexing has gotten a lot of press in the optical communications field, especially since it was offered as a promising long-distance transmission format in both coherent and direct detection.**

*Keywords*- **Glass fibers, Telecommunications, OFDM, coherent, direct detection.**

## I. Introduction

The increased demand for bandwidth and fast data speeds has been driven by the growth of Internet traffic, which includes data, voice, and video services. Global research and development activities have recently been launched to address the growing need for high-capacity transport networks, primarily for 100G Ethernet and beyond. Bandwidth expansion and spectral efficiency improvement are the two key difficulties that must be found in order to boost the data throughput to 100 Gb/s per wavelength.

### *A. Bandwidth Expansion*

Increasing the transmission bandwidth per wavelength, either optically or electronically, is one way to boost system capacity. There are two extensively used strategies in optical communication to boost transmission capacity. The first method involves adding several optical carriers to increase bandwidth. Wavelength division multiplexing is a method that has been investigated and used (WDM). WDM is one of the most cost-effective methods for improving the performance of optical fiber links .

### *B. Enhancing the Spectral Efficiency*

In optical communication, spectral efficiency, which is the information capacity per unit of bandwidth, is the most important figure of merit. Currently, optical networks use intensity modulation and direct detection for transmission and also use binary modulation to reduce the complexity of the transceiver. However, with binary modulation, the spectral efficiency will not exceed 1 bit / s / Hz [6]. Many advanced modulation formats in signal amplitude, phase and polarization have recently been explored to increase system capacity. Coherent detection in combination with advanced modulation technology can easily achieve multi-bit / s / Hz spectral efficiency.

## II. Optical Fiber Communications Systems

An optical fibre is a flexible, transparent fibre that is slightly thicker than a human hair and is constructed of extruded glass (silica) or plastic. It can transmit light between the two ends of the fibre as a waveguide or "light pipe." Fiber optics is a branch of applied science and engineering concerned with the design and application of optical fibers.

### *A. Optical Communication :*

A communication system based on optical fibre is similar to any other communication system. A transmitter, a receiver, and a communication channel are the three main components. The distinction between a fiber-optic communication system and other communication systems is that the communication channel is an optical fibre, and the transmitter and receiver are designed to meet the communication channel's requirements, as shown in Figure 1.

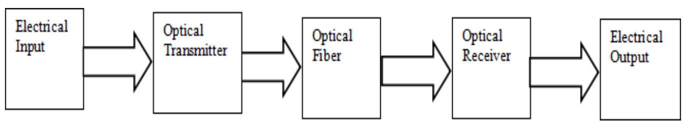


Figure1. Optical Communication System

### *B. Fiber Attenuation:*

Attenuation, also known as fibre loss, transmission loss, or power loss, refers to a decrease in the intensity or strength of light as it travels over a fibre. The main cause of attenuation in an optical fibre is scattering and absorption, which is measured in dB/km. The ratio of input optical power to output optical power after L length of optical fibre is known as attenuation. This ratio is a wavelength function and may be written as

$$\alpha = \frac{10}{L}\log\left(\frac{P_{out}}{P_{in}}\right)$$

*C. Fiber Dispersion*

The spreading of the light pulse as it passes along the fibre is known as fibre dispersion. This causes the pulse to overlap with the nearby pulses, making it difficult to precisely reconstruct the original signal. During the transmission of a signal, numerous types of signal dispersion can occur, such as chromatic dispersion and polarization-mode dispersion.

*D. Optical Modulation*

The first consideration in designing an optical communication system is how to convert an electrical signal to an optical signal. An optical modulator, either a direct or external modulator, is required to convert the electrical signal to an optical signal.

*E. Wavelength Division Multiplexing(WDM)*

Wavelength Division Multiplexing (WDM) is a key component in the evolution of optical communications. It has the ability to increase system flexibility while also simplifying network design. By delivering various wavelengths across a single fibre, WDM systems help to increase the system's capacity[18]. WDM systems enhance the data rate transported over a single fibre by employing several wavelengths, each carrying a separate channel. WDM divides the optical spectrum into smaller channels that can concurrently send and receive data.

## III. Orthogonal Frequency Division Multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, used in applications such as television broadcasting and audio broadcasting, DSL Internet access, wireless networks, power-line networks, and 4G mobile communications. Two fundamental advantages of OFDM are its robustness against channel dispersion and its ease of phase and channel estimation in a time varying environment. OFDM is a frequency division multiplexing (FDM) scheme used as a digital multicarrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme such as QAM or PSK at a low symbol rate. However, OFDM also has disadvantages, such as high peak to average power ratio (PAPR) and sensitivity to frequency and phase noise.

Figure shows the block diagram of transmission system using OFDM. At the transmitter side, the high rate digital data stream is split into N parallel streams. Each stream is mapped to a symbol stream using modulation scheme (QAM, PSK, etc). The symbols are modulated onto the sub-carrier using IFFT to transform the OFDM signal from frequency domain to time domain. After IFFT operation, a cyclic prefix or guard interval is added to prevent the overlapping between sub-carriers, and then the OFDM signal is converted to analog signal by using D/A converter. After that the signal is sent through the channel after performing a P/S conversion. At the receiver side, the received data is converted to parallel and the guard interval or cyclic prefix is removed. Then the signal is demodulated by using FFT algorithm and demodulates during the M-Aryde -modulator which could be either QAM or PSK. Finally, the data is converted to serial to get the original data

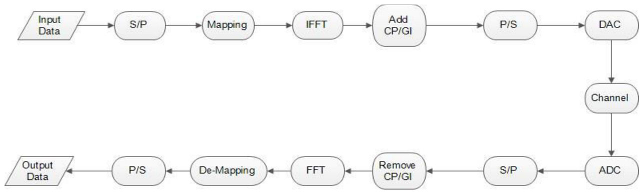


Figure 2. OFDM Block Diagram

## IV. System Design

The OOFDM simulation results are presented in this chapter. Optisystem software was used to create this system. The OFDM modulation technology Quadrature Amplitude Modulation (QAM) is used. A basic introduction and explanation of the QAM technology will be shown, as well as Optisystem software.

The model of the OFDM system will be given, as well as the 16 QAM OFDM system.

*A. Optisystem Simulation Software*

Optisystem is a software platform that allows users to plan, test, and simulate optical links in modern optical networks' transmission layer. This application provides a large range of optical and wireless components for planning and building a full optical network, which is a low-cost and time-saving strategy that allows the researcher to work more efficiently.

Users can simulate and design with Optisystem.

1. Access Networks
2. Co-Simulation
3. Advanced Modulation
4. Dispersion Management
5. Optical code division multiple access for Passive optical networks
6. Multi mode Systems
7. Optical Amplifiers, receivers, transmitters
8. Fiber Analysis and Design

## V. Simulation Results and Discussion

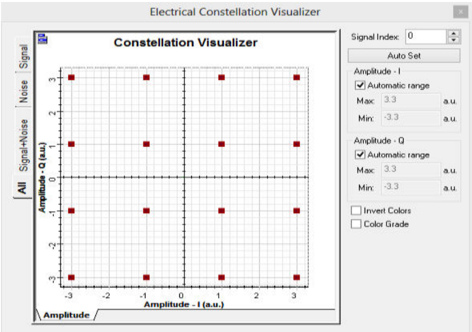


Figure3. 16 QAM Encoder Constellation Diagram

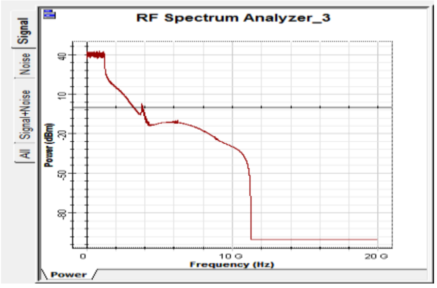


Figure4. Filtered OFDM signal by LP filter

In the frequency domain, Figure 5 shows the modulated OFDM signal after quadrature modulation. The modulated OFDM signal has a bandwidth of 12 GHz and a power of 40dB.

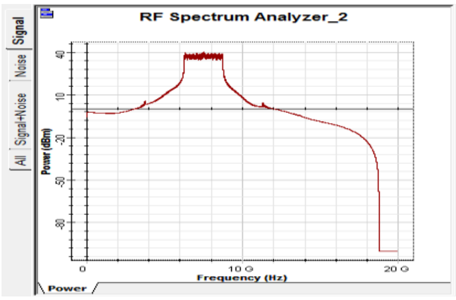


Figure5. OFDM Signal in the Frequency Domain

The signal will then be carried through the optical fibre, where it will be received after two 50-kilometer loops. The modified OFDM signal after passage across the optical connection is shown in Figure 6.

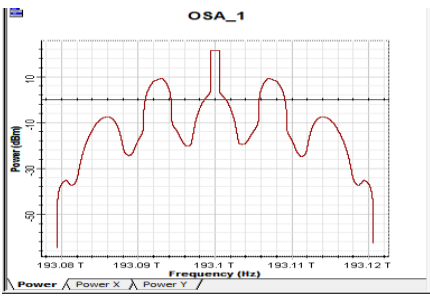


Figure6 OFDM Signal after the Optical Link

Figure 7 displays the system's RF spectrum at the DD-OFDM receiver after two 50-kilometer optical loops. With side noise, the RF power is measured at -17 dB.

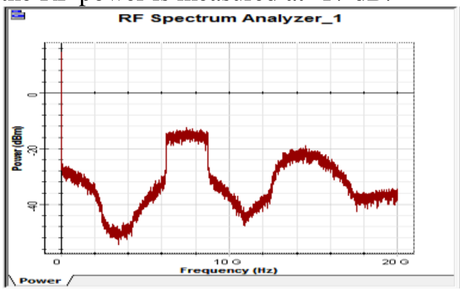


Figure7. Received RF Signal in the Frequency Domain

The resultant signal following the BPF with 2 GHz bandwidth from two sides of the centre frequency at 7.5GHz is shown in Figure 8.

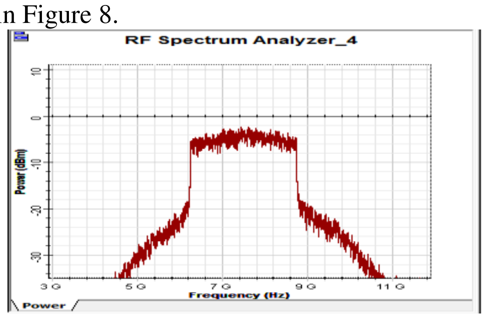


Figure8. RF Signal after BPF

The constellation diagram of the system after 100 km SMF at the DD-OFDM receiver side is shown in Figure 9. The signal is twisted and garbled due to chromatic dispersion, as can be observed.

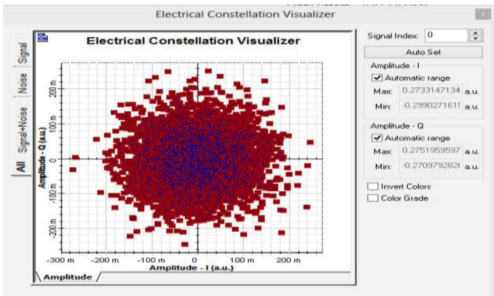


Figure9 Constellation Diagram of the 10 G bits/s One Users DD-OFDM at the Receiver Side afterSMFof100 km

Three parameters were examined after modulation and demodulation to assess the system's performance and signal quality. The Q factor, the bit error rate, and the eye diagram are the three metrics in question. The quality factor is a number that reflects how good a signal is. A greater Q factor indicates how good a signal is. The Bit Error Rate (BER), on the other hand, is the ratio of the number of bits with errors to the total number of bits received, and it aids in determining the optical connection's quality. One of the most useful tools for studying the system is the eye diagram. The eye opening can reveal the signal's noise and how it distinguishes logic 0 from logic 1.

Table4.2SignalDetailsattheReceiverfor10Gbits/s

| Signal details at the receiver | |
|---|---|
| Max Q Factor | $1.01\times10^{50}$ |
| Min.BER | 0 |
| Eye Height | 2.02 |
| Threshold | -1.01 |
| Decision Inst | 0.625 |

The RF spectrum of the system at the DD-OFDM receiver side after 400km SMF with a 20dB optical amplifier power is shown in Figure 4.19. The RF power is reduced as the distance increases from -10dB at 100km to -43dB at 400km.

## VI. Conclusions

Using direct and coherent OFDM detection, three separate systems were modeled for different data rates in this paper. The first project was DD-OFDM, which uses a 7.5GHz frequency carrier. This system investigated different transmission lines with a data rate of 10Gbits/s and modulation type of 16-QAM, 256 subcarriers, and 512 FFT points. It has been discovered that as the transmission length rises, the Q-factor lowers, resulting in a lower BER value. The best BER value was 0.

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