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A Review on analysis of Non-linearities & Dispersion reduction techniques in O-OFDM system

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Abstract: The growing requirement for various services and the rapidly expansion of the Internet are producing the development of high channel capacity and flexible optical communication networks. Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique in optical communication as it belongs to multicarrier modulation which carries the data information over many subcarriers to achieving high data rate without inter–symbol interference. Advantage of optical orthogonal system is spectrum efficiency and channel robustness. In this presented paper review of multiple techniques used to improve the performance of optical OFDM communication systems in long haul fiber optic channels such as Multi Carrier – Code Division Multiplexing Access (MC-CDMA), Single Sideband Subcarrier-Multiplexed Dense-Wavelength-Division-Multiplexing (SSB/SCM/DWDM) and Multiple Optical Phase Conjugate (OPC) etc. To overcome the transmission impairments several dispersion methods such as dispersion effects chromatic and polarization mode dispersion (CMD, PMD) are presented for increasing spectral efficiency.

Keywords: CO-OFDM (coherent optical orthogonal frequency division multiplexing), OFDM (Orthogonal frequency division multiplexing),WDM (wavelength division multiplexing), OPC (Optical phase conjugation),QAM (quadrature phase shift keying), ROF (radio over fiber), WDM (wavelength division multiplexing)

1. INTRODUCTION

Spectrum efficiency and channel robustness are the main key features of orthogonal division multiplexing which one is used in broadband communication. OFDM belongs to multicarrier modulation which carries the data information over many subcarriers. OFDM, a modulation as well as multiplexing technique is the origin of several telecommunications standards counting digital terrestrial television (DTT), WLAN, and digital radio broadcasting. The optical data transmission rate can burst up to Terabit per second (Tb/s) in long haul distance as O-OFDM reduces the dispersion (chromatic as well as polarization mode) effect very efficiently. Due of this reason O-OFDM technique is implemented in WDM system to increase the system efficiency. As ability of OFDM technique, its benefit is to reduce the effect of selective fading and decrease Inter-symbol Interference (ISI) in both wireless and wired transmission system. [19].For further improvement in spectral efficiency, OFDM uses the concept of fast Fourier transform and spectral efficiency can be improved by the use of combination of OFDM with phase modulation, this result in the drastically decrease in the system non-linearity [1].

A. OFDM architecture

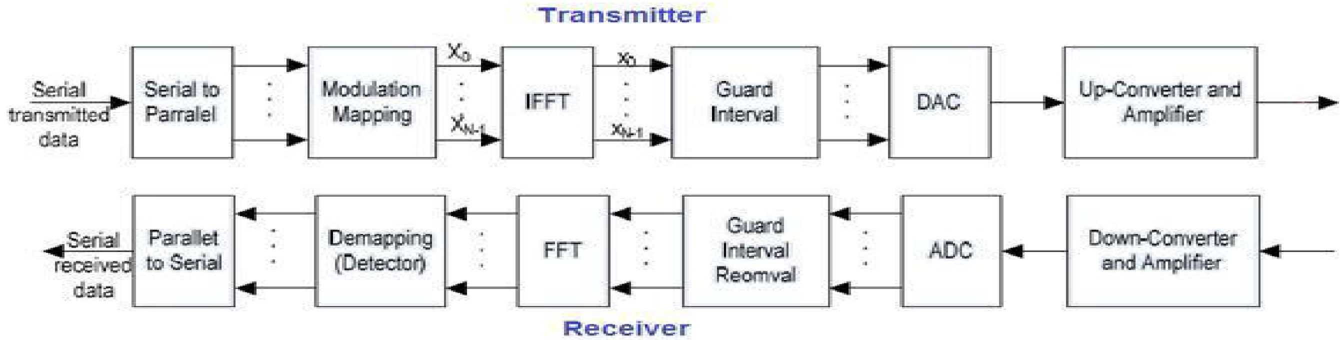

Fig.1.1 OFDM (orthogonal frequency division multiplexing). [19]

Fig1.1 represents the transmitter and receiver section of the OFDM system. On transmitter side, data is transmitted into N number of data lines where each data line uses some modulation scheme i.e. QAM, PSK, etc. that laid and mapped to a symbol stream. The symbols in OFDM system uses the inverse discrete Fourier transform (IDFT) which modulates the various subcarriers. IDFT is a technique in which OFDM symbol is converted from the frequency domain to time domain. A cyclic prefix is padded to the OFDM symbol after the IDFT operation and then followed by digital-to-analog converter (DAC). The output of DAC is baseband signal which is transmitted after it is up-converted in frequency.

On the receiver side, signal is down-converted to baseband signal. Then signal is followed by an analog-to-digital converter (ADC), in which signal is converted from analog to digital. Then these samples are fed into the discrete Fourier transform (DFT) in which time domain is converted into frequency domain, after removing guard interval and data is detected finally. [19]

B. Types of OFDM: The optical OFDM systems can be classified into three approaches according to the detection scheme are as follows:

(I) DDO-OFDM (Direct Detection Optical OFDM): DDO-OFDM is suitable for low-cost and short distance applications. [7]

(II) CO-OFDM (Coherent-Optical OFDM): CO-OFDM aims to achieve best receiver sensitivity with high spectral efficiency [7]. CO-OFDM long-haul transmission compared to DDO-OFDM.

(III) SCO-OFDM (Self coherent Optical OFDM): This scheme modifies CO-OFDM as it extracts the optical carrier from the optical OFDM signal at the receiver side for coherent interference. This is a next generation spectrally efficient advanced modulation approach. [14]

Nowadays, coherent optical orthogonal frequency division multiplexing (CO-OFDM) is used in recent work of optic communication systems [15]. The CO-OFDM produces very high spectral efficiency which helps to overcome transmission impairments such as dispersion effects (CMD, PMD) [8]. However, fiber nonlinearity impairments such as intrachannel four wave mixing (FWM) and cross phase modulation (XPM) between the OFDM subcarriers create high degradation effect to launch powers.

2. Related WORK ON LONG HAUL OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING) SYSTEM.

In the past few decades, the importance of multi-carrier communication system has been established. Multi-carrier communication system such as OFDM has been evolved as one of such scheme which is bandwidth efficient, high spectral efficiency, easy equalization and robustness to frequency selective fading channel. The OFDM has been adopted by many broadband wireless communication standards like IEEE 802.11, 802.16 and UWB communication systems. In this paper the main focus of work is to provide an appropriate solution to each and every major problem like high PAPR, frequency synchronization and fiber dispersion. By use of OFDM, improvement in the spectral efficiency and efficient BER.

3. OOFDM-ROF (OPTICAL ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

The block diagram of OFDM-RoF system is shown in figure 3.1. The digital data is divided into parallel stream and is fed into OFDM transmitter that further carried via fiber optical link. At the receiver end, the data is first received by photo detector which converts the arriving photonic stream back into electron stream, thus the optical signals are converted back to electrical signals. In the OFDM receiver, the signal then recombines again to get back the original data. [11]

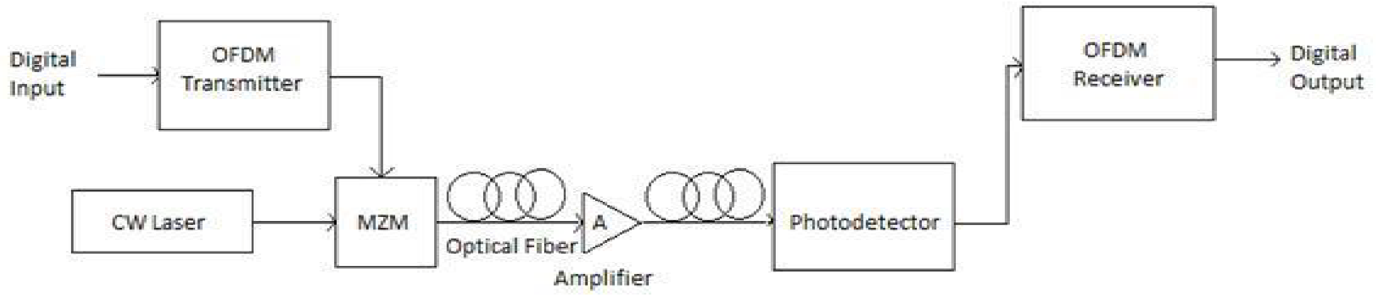

Fig.3.1 Block diagram of OOFDM-ROF system. [11]

In 2002 R.S. Kaler, T. S. Kamal and Ajay K. Sharma had demonstrated the single mode fiber (SMF) in second and third order dispersion that had minimum impact on intensity and frequency on optical system. The system provides better performance in the long distance, in the range of acceptable BER and for compensating pulse width or dispersion. In this paper, Peak-to-Average Power Ratio (PAPR) reduction technique for 16-QAM OFDM systems and BPSK OFDM system techniques were used. The algorithms were designed to use a scrambling sub code for controlling PAPR and a correction sub code for controlling error. [2]

CDMA was a form of multiplexing, which allows numerous signals to occupy a single transmission channel by optimizing the use of available bandwidth. In year 2003, Multi-Carrier (MC) CDMA was presented which was combined technique of Direct Sequence (DS) CDMA (Code Division Multiple Access) and OFDM techniques. MC-CDMA system was well suited for a high-speed data transmission, whereas the DS-CDMA system could see more than around 10 paths in the multipath delay profile. A DS-CDMA receiver would lose almost all of the received signal energy, whereas a MC-CDMA would effectually gather it, although a fraction of the energy would be misplaced in the guard interval. The MC-CDMA system might be one of the major candidates for 4G mobile communications where high scalability was required in possible transmission rates. [3]

In year 2004, the fundamental linear and nonlinear system with limitations of multichannel SSB/SCM/DWDM systems were presented. With conventional Sub Carrier-Multiplexed (SCM) transmission system, lower and upper subcarrier sidebands appear on both sides of an optical carrier, and their phases tend to rotate with respect to each other due to the chromatic dispersion in a standard single-mode fiber (SMF). To understand the transmission limitation of multiple narrow single-sideband subcarrier-multiplexed (SSB/SCM) signals, combination of SSB/SCM with dense-wavelength-division-multiplexing (DWDM) systems were used to analyze cross-phase modulation-induced crosstalk. Several multichannel SSB/SCM/DWDM systems with transport capacities of 10 or 20 Gb/s per wavelength, having wavelength spacing of 25, 50, and 100 GHz, were also used to understand the fundamental transmission limitations. So, in this year the fundamental linear and nonlinear system limitations of multichannel SSB/SCM/DWDM systems were studied. [4]

For a long distance communication and to reduce non linearity in communication, orthogonal frequency division multiplexing (OFDM) with optical single sideband modulation were compensated for dispersion in 4000-km 32×10Gbps WDM SMF links with 40% spectral efficiency in 2006 .OFDM required no reverse feedback path as it could compensate the rapid plant variations.OFDM used suppressed-carrier OSSB to compensate the dispersion in ultra-long haul WDM optical links. The fiber nonlinearity did not strongly affect the OFDM signals, even though their sub-carriers were spaced by only 10 MHz .Thus OFDM could be an attractive technology for adaptive compensation of systems with fast variations, either environmental or deliberate as it did not require a feedback path with its intrinsic time delay. [5]

In 2007 OFDM with adaptive method were used to increase the spectral efficiency and receiver sensitivity. OFDM and optical single sideband modulation was used to compensate for chromatic dispersion in ultra long-haul wavelength-division multiplexed (WDM) systems. OFDM provided a high spectral efficiency, did not require a reverse feedback path for compensation, and had a better sensitivity than non return to zero and OFDM was a well-established technology used in this paper that can compensate for all frequency-dependent amplitude and phase characteristics of a communications channel, so that it offered a robust adaptive method and combination of OFDM and suppressed-carrier OSSB transmission can compensate ultra long-haul optical links, with better receiver sensitivity than a back-to-back NRZ system [6].

Coherent Optical Orthogonal Frequency Division Multiplexing (OFDM) propagation and detection over multi-span long-haul fiber links in year 2008, comprehensively and rigorously analyzed the impairments due the combined effects of FWM, Dispersion and ASE noise. Accounting for the phased-array concept and applied the compact OFDM design. The system performance of a 40 Gbit/s coherent OFDM system, over standard G.652 fiber, with cyclic prefix based electronic dispersion compensation but no optical recompense along the link. The transmission variety for 10^{-3} target BER was almost tripled from 2560 km to 6960 km. [9]

According to the studied done in the year 2010, the use of OFDM to enhance the capacity of multi mode fiber (MMF) based optical interconnect intended for data center applications was analyzed. In this paper solution for intermodal dispersion of the MMF as well as for modulation bandwidth drawbacks of the lasers that was responsible for frequency-dependent attenuation. Adaptively modulated OFDM was reviewed, and new results using simulations was presented for assessing the capacity of these links for lengths equal to 300 m, assuming graded-index MMF at 850nm wavelength. [10]

Coming to the year 2011, the major disadvantage of Coherent Optical Orthogonal Frequency Division Multiplexing (CO-OFDM) system was its sensitivity to fiber nonlinearity. Nonlinear electrical equalizer based on Volterra model had been demonstrated that was capable of compensating fiber nonlinear distortion in an OOK or PSK optical communication system. The Volterra model based electrical equalizer had been capable of compensating intra-channel nonlinearity of the CO-OFDM system.[12] Also used a small complexity Partial Transmit Sequence (PTS) scheme with applying a new phase sequence because PTS was the most important techniques used for reducing the PAPR in OFDM system in this year. [13]

In year 2012 presented the OFDM in optical fiber communication applications increased its potential of electrical equalization to mitigate chromatic dispersion (CD) and polarization mode dispersion (PMD). The high peak-to-average power ratio (PAPR) produced by large amplitude fluctuations of the modulated waveform was one of the major drawbacks of this technique. In fiber optical OFDM systems, PAPR reduction techniques were important challenges in order to increase their tolerance to optical modulator inter modulation and fiber nonlinearity impairments. [16]

In year 2013, discussed to reduce the cost of optical OFDM based on the SOA had great potential for next generation optical access networks and PONs due to its high flexibility in bandwidth manipulation, high spectral efficiency and reduced PAPR. In most cases and conditions, the benefit of adaptive bias PAPR optimization, adaptive peak-to-peak PAPR optimization, or adaptive clipping PAPR optimization could improve the system performance significantly. Consequently, it was possible to reach a required pre-FEC bit error rate (BER) value of 10^{-3} at distances of few 10 km, which deal with most of PON and access applications requirements. [17]

Radio over fiber (ROF) was a hybrid system having both fiber optic link and free-space radio path. In year 2014 ROF systems microwave data signals were modulated onto an optical carrier at a central station and transported to remote sites or base station using optical fiber. 10 Gb/s optical OFDM-ROF transmissions links with distance of 50 km were reported to improve the performance by usage of a square root module (SQRT). By this system, the improvement in the system flexibility and provides a very large coverage area without increasing the cost and difficulty of the system. Radio over fiber transmission functioning of OFDM signals for dual-band of 2.4/5 GHz wireless LAN systems with very low-data rate.[18]

CO-OFDM was a very attractive modulation and multiplexing technique that was used in wideband optical systems as well as optical wireless systems. In year 2016, the performance of utilizing multiple optical phase conjugate (OPC) modeled in CO-OFDM system as a midlink spectrum inverter had been analyzed in order to improve the performance of system in long-haul fiber-optic channel. In this paper, COOFDM system designed at 30Gb/s, 50Gb/s and 100Gb/s which successfully transmitted over 1800Km, 1440Km and 1080 Km link length without using any optical phase conjugation module. Further multiple OPC modules used in order to compensate effects of Kerr non linearity. The long distance of 8400Km had achieved with acceptable BER limits by incorporating 6 OPC modules each after 1200Km at 30Gb/s and system performed best at 12dB input power and effects of SPM decreased by using multiple OPC modules.[20]

4. CONCLUSION

The importance of multi-carrier communication system has been established in the present communication era. Multi-carrier communication system especially OFDM has been evolved as one of such scheme which is bandwidth efficient, high spectral efficiency, efficient BER and for long distances. In CO-OFDM Optical phase conjugation (OPC) has been analyzed to enhance the system link length by mitigating the effects of non linearity's. Maximum achievable distance with 10^{-4} BER is 8400Km by using 6 OPC's. In this paper the main focus of work is to provide an appropriate solution to each and every major problem like high PAPR and fiber dispersion. Dispersion compensation using symmetric SMF and DCF configurations has been used in this works for maximum distance 1800Km .However, in future using more suitable compensation method distance can be enhanced. Use of 16 QAM and 64 QAM may enhance system capacity and same system analyzed from WDM systems this can be further reduced for more bandwidth utilization and some other techniques can be introduced for further network sharing.

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