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Analysis of the OFDM Signal and Optical OFDM signal

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***Abstract*:** The application of the optical sensors and the optical devices make it possible to realize the configuration of an all optical OFDM system. The use of optical OFDM is proposed for achieving high bit rate data transmission .It is also utilized for reducing the inter symbol interference. The infrared radiation ,as a medium for the high speed and short range wireless digital communication has been applied in optical wireless communications. This proposed system will show the promising results for a high speed optical wireless channel. In this paper, the history of research and development on OFDM and COFDM is reviewed. Then, the basic principles, performance and implementation of OFDM and COFDM are examined. Analysis is given to enable the selection of key elements for meeting the constraints of the required applications. Based on the ATV channel model, performance expectation of COFDM under imperfect channel conditions and implementation issues are examined in details.

***Index Terms*:** Cyclic Prefix, DFB Lasers, Orthogonal Frequency Division Multiplexing, Inter symbol Interference (ISI) Inter channel Interference(ICI).

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is used in many broadband wired and wireless communication systems but until recently has not been used in optical communications. Recent research has shown that OFDM can be applied to many optical communication systems, including both single mode and multimode optical fiber applications and optical wireless systems. At this year's OFC conference two experimental demonstrations were presented of transmission at 20 Gb/s over hundreds or thousands of kilometers of single mode fiber using one optical carrier. One of the main benefits of these fiber-optic OFDM systems is that these transmission systems are realized without any kind of optical chromatic dispersion compensation. In both cases compensation was achieved digitally in the receiver using the properties of OFDM. Although both papers used OFDM, two fundamentally different approaches were used, namely direct-detection optical OFDM (DD-OOFDM) and coherent optical OFDM (CO-OFDM). The main advantages of DD-OOFDM is that it is a more cost-effective solution and very tolerant to laser phase noise, whereas CO-OFDM is a more spectrally efficient solution and theoretically provides higher ASE-sensitivity. In this talk, Sander Jansen will discuss CO-OFDM as a modulation technique for long-haul transmission systems. Several design and implementation aspects of a CO-OFDM system are reviewed and in particular phase noise compensation is discussed.

Orthogonal frequency division multiplexing (OFDM) has been widely employed into numerous digital standards for broad-range of applications such as digital audio/video broadcasting and wire line/wireless communication systems . Recently it has been shown that OFDM can be applied in optical long haul transmission systems and had many advantages over conventional single-carrier modulation format [1]. Many key merits of the OFDM techniques have been studied and proven in the communications industry. Firstly, the frequency spectra of OFDM sub carriers are partially overlapped, resulting in high spectral efficiency. Secondly, the channel dispersion of the transmission system is easily estimated and removed, and thirdly, the signal processing in the OFDM transceiver can take advantage of the efficient algorithm of FFT/IFFT with low computation complexity.

Recently, an equivalent optical domain multi-carrier format, called coherent optical OFDM (CO-OFDM) has been proposed for long haul transmission [2]. In the mean time, incoherent optical OFDM (IO-OFDM) has also been proposed independently, and has been shown to have similar dispersion tolerance with a much simpler detection scheme. However, the CO-OFDM is superior to IO-OFDM in spectral efficiency, OSNR requirement, and PMD insensitivity. It is well-known that OFDM is generally susceptible to nonlinearity and phase noise owing to high peak to average power ratio (PAPR) [3]. Therefore it is critical to investigate and improve the CO-OFDM system transmission performance including fiber nonlinearity, in order to ascertain its suitability for optical transmission.

Due to the recent advances of digital signal processing (DSP) and very large scale integrated circuit *0* technologies, the initial obstacles of OFDM implementation, such **as** massive complex computation, and high speed memory do not exist anymore. Meanwhile, the use of fast Fourier transform (FFT) algorithms eliminates arrays of sinusoidal generators and coherent demodulation required in parallel data systems and makes the implementation of the technology cost effective. Another reason for the growing popularity of OFDM is that only very recently its optimal performance has been proven theoretically [4].

Although it has long been used for digital data transmission, OFDWCOFDM has been studied in Europe and elsewhere for potential digital X-IDTV terrestrial broadcasting. Various projects and prototypes of OFDWCOFDM systems have been engaged and

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demonstrated publicly. Among them are HD-DIVINE (Digital Video Narrowband Emission) developed by Nordic countries, DIAMOND developed by Thomson-CFSLER, STERNE (System de Television en Radio diffusion Numeriqe) by CCETT (a joint venture of France Telecom and TDF), dTTt, (digital Terrestrial Television broadcasting) by Commission of the European Communities (CEC), EP-DVB (European Project on Digital Video Broadcasting) by European national administrations and private industry, SPECIRE (Special Purpose Extra Channels for Terrestrial Radio communication Enhancements) by NTL of U.K. and HDTVT (Hierarchical Digital **TV** Transmission) in Germany. COFDM research has also been carried out by NHK and a few Japanese electronic manufacturers [5]. In North America, the FCC Advisory Committee on Advanced Television Service officially accepted an 8-VSB modulation technique developed by Zenith/the Grand Alliance for the final testing. However, the advisory committee indicated that it will study and monitor the development of coded OFDM (COFDM).

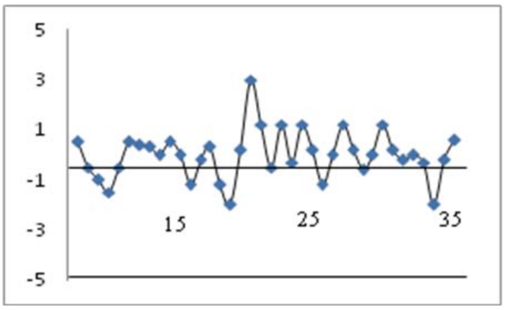
Encouraged by the potential advantages of COFDM, some U. ***S.*** and Canadian broadcasters have decided to investigate the technology. Recently, several U. ***S.*** and Canadian broadcaster organizations formed a consortium and issued a Request for Quote to solicit potential bidders to build COFDM hardware for evaluation.3 The debate on COFDM versus vestigial sideband (VSB) modulation or quadrature amplitude modulation (QAM) for terrestrial HDTV broadcasting has been engaged in the past and there is no sign that it will end soon. One reason is that neither COFDM nor VSB has a clear advantage in all of the performance aspects. Some differences may be based on specific system implementation. Another reason is that neither approach had been tested in the field extensively [6].

Recently, the proposed 8-VSB modulation subsystem has been tested in Charlotte, NC by PBS, MSTV, and Cable Labs. It is expected that the test results will provide valuable information on the performance of the 8-VSB system. In this paper, an overview of OFDWCOFDM research and development is presented. The motivations of using OFDMKOFDM and their applications are discussed. The principles of the technology are examined in details. Analysis is given on how to select key system elements. In addition, the performance expectations of COFDM under imperfect channel conditions and implementation issues are examined.

II. POWER EFFICIENT OPTICAL OFDM

A. OFDM signals:

In OFDM, signals are transmitted in parallel on a number of subcarriers at different frequencies. Usually quadrature amplitude modulation (QAM) modulates each sub carrier. The transmitter uses an inverse fast Fourier transform (IFFT) to generate a sampled waveform. Let X(m) be the complex number representing the constellation point on the mth subcarrier of a given symbol[7]. Then the baseband time domain samples for that symbol are given by x(k) where



Time

Figure 1 a) all subcarrier modulated

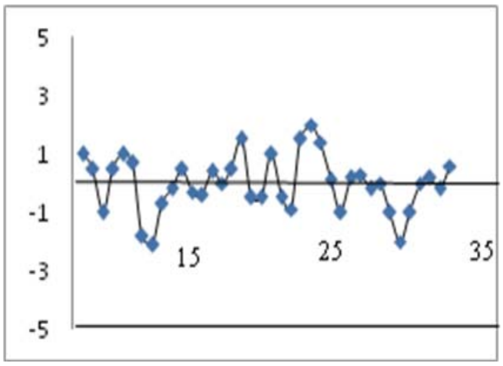


Figure 1 b) only odd subcarriers modulated.

And N is the size of the IFFT. In general, x(k) and X(m) are complex. For baseband systems the frequency domain vector X is constrained to have Hermitian symmetry, so that x(k) is real. Fig. 1a shows samples of a typical OFDM baseband symbol and the waveform x(t) which could be generated from them. Fig .1b shows a symbol where only odd subcarriers are used. In this case, for clarity, N¼32, although typical values range from 64 to 8192. OFDM signals have a high peak-to-average power ratio. For N_64 the central limit theorem applies and the distributions of x(k) and x(t) are approximately Gaussian.

B. Optical OFDM:

Optical OFDM systems [8] a unipolar signal xdc(t) is derived from x(t) by adding a DC bias. In Fig.2a the bias is twice the standard deviation of x(t). For a fixed bias, there will be occasional OFDM symbols with large negative peaks which will be clipped, adding noise to the signal. Because xdc(t) gives the intensity of the optical signal, the average transmitted optical power is approximately equal to the DC bias, which in this example is 2, for an RMS electrical power of unity. Thus this system is very inefficient in terms of optical power.

We propose using no bias. In the new scheme the signal xc(t) shown in Fig .2b would be transmitted. All negative values are forced to zero. We will show that if the subcarrier frequencies used for data transmission are correctly chosen, the data can be retrieved from a signal of this form with little, or for some configurations, no in-band clipping noise.

Optical OFDM Signal consisting of the DC Biased OFDM signals and clipped OFDM signals. The difference

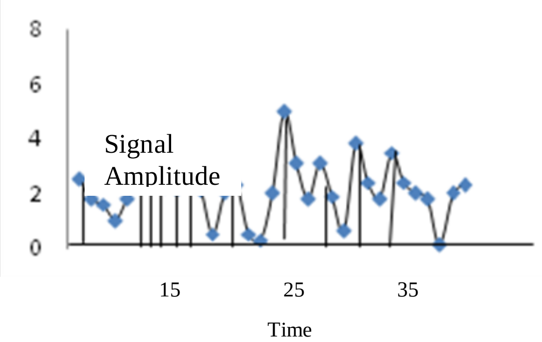


Figure 2 (a) Optical OFDM Signal DC Biased OFDM

Between these two are given in the figure 2a and 2 b , showing that the values of the signal amplitude is always positive for the DC biased OFDM where as the values of signal amplitude are almost Linear in nature.

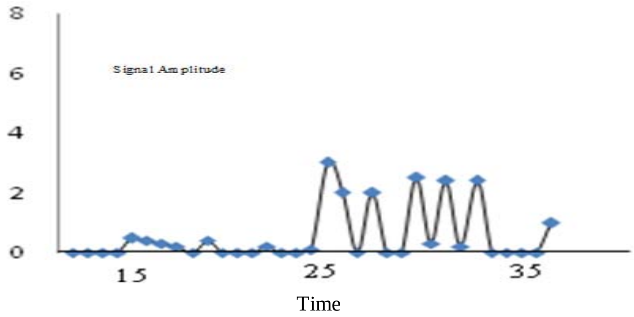


Figure.2 (b) Clipped Optical OFDM Signal

Spectral efficiency is an important aspect of WDM systems. Optical OFDM's spectral efficiency is up to 1 bit/s/Hz, in principle. This method utilizes the orthogonality between the spectral profiles of each channel [9]. The N multiplexed signals, whose frequency spacing is ***f***, can be represented as

$$S(k\Delta t) = \sum_{n=0}^{N-1} d_n(k\Delta t) \cdot e^{j2\pi(f_0+n\Delta f)k\Delta t}$$

Where *dn*(*t*) is the data sequence of the *n*th channel, *T* is the symbol interval and *t* = *T*/*N* is the sampling interval. The multiplexed data sequence can be separated using a discrete Fourier transform (DFT),

$$d_n = \sum_{k=0}^{N-1} S(k\Delta t) \cdot e^{-j2\pi(f_0+n\Delta f)k\Delta t}$$

We can implement the optical DFT as shown in Fig. 1. In this eq., the terms S (*k t*) and e-*j2* **k** *f t* physically represent an optical delay line with delay time *k t*, and a phase shifter, respectively. The summation means an optical coupler. Furthermore, we require

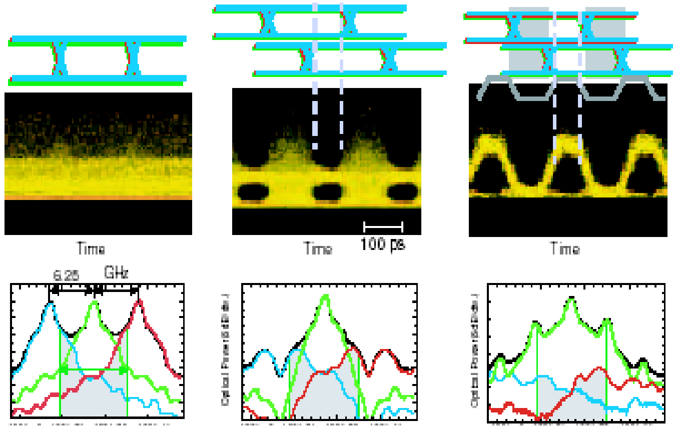


Figure. 3

(a) multiplexed Signal (b) after MZ filter (c) After (EA) gate signal

Bit synchronization at the input and an optical gate at the output, because the optical DFT is effective for the duration of unchanged *dn*(*t*). This scheme was demonstrated as shown in Fig. 2. We used a Mach-Zehnder (MZ) filter for the separation and an EA modulator for the gate. In the multiplexed signals, the spectra overlapped considerably and no eye opening was observed[10]. After the MZ filter, the eye opening was observed only when the same bit overlapped itself. After the EA modulator, only a clearly opened eye pattern was observed, and error-free operation was obtained. This scheme can completely separate one modulated spectrum from other signals that have a substantial overlap with 0.8 bit/s/Hz of spectral efficiency.

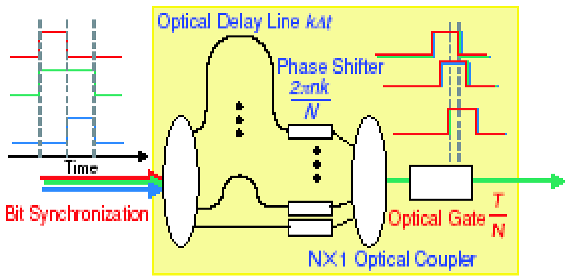


Fig. 1 Optical Circuit for Discrete Fourier Transform

III. SIMULATED RESULTS

Simulations using the introduced OFDM setups have been conducted in order to show the impact of differential group delay on the transmission performance. Throughout this work we set the bit-rate to 10 Gb/s and use a sub-carrier spacing of approximately 39 MHz which corresponds to an OFDM symbol duration of 25.6 ns. 3.2 ns thereof is the duration of the cyclic prefix, i.e. *rCP* = 1/8 of the original OFDM symbol is added for avoiding inter-symbol interference [11].

This fraction of the transmitted signal carries no information and finally leads to a OSNR penalty of dB 5. 0) 1 lg(10 ¡Ö + · *CP r* . At first the following results show the bit error ratio (BER) versus OSNR (noise bandwidth 12.5 GHz) for the OFDM setup using coherent detection. The number of sub-carriers was set to 256; BPSK modulation was used, channel estimation is based on 3 preamble symbols known to the receiver.

All the simulations were carried out without incorporating chromatic dispersion. Furthermore the modulator as well as the fibre were assumed to be perfectly linear; quantization effects have been neglected (some implementation impairments for setup b) are discussed in [12]).

A further aspect which leads to implementation losses shall be neglected here: non-zero laser line width. The authors of [12] assume a line width of 100 kHz. It is well-known that an OFDM system is distinctly more sensitive to non-zero carrier line width than single carrier systems. For a given oscillator line width *LW* there is an approximate SNR degradation .*SNR* (in dB) of[5] is as

$$\Delta SNR \approx \frac{10}{\ln 10}\,\frac{11}{60}\left(\frac{4\pi\,Lw}{\Delta f}\right)\frac{Es}{No}$$

The crucial measure is the ratio of the line width and the sub-carrier spacing .*f*. Note that the degradation is proportional with *ES/N0*, which denotes the (linear) SNR within the considered sub-carrier. Given *LW* equalling 100 kHz and .*f* = 39 MHz the approximate SNR degradation is 0.26 dB for a sub-carrier SNR of 10 dB. In this case a laser line width of 2 MHz leads to 5.1 dB penalty.

A. Simulation through I/Q Modulation and Coherent Detection:

Fig. 3 shows the BER performance for various DGD values up to 70 ps (for worst case launch). We observe distinct performance degradation for rising DGD measures.

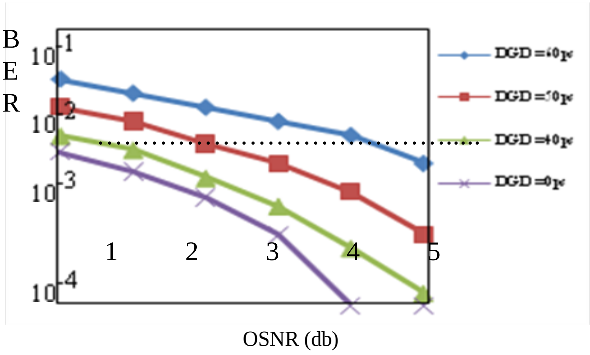


Figure. 5 BER performance (coherent system, 256 subcarriers, BPSK).

This is because DGD depolarizes the optical signal. The coherent detector down-converts the signal fraction which is 45°-linearly polarized; the signal fraction of the orthogonal state of polarization is lost. In terms of transfer functions this effect causes fading as depicted in Fig. 4. The SNR of the outer sub-carriers is reduced which leads to an increasing bit error ratio.

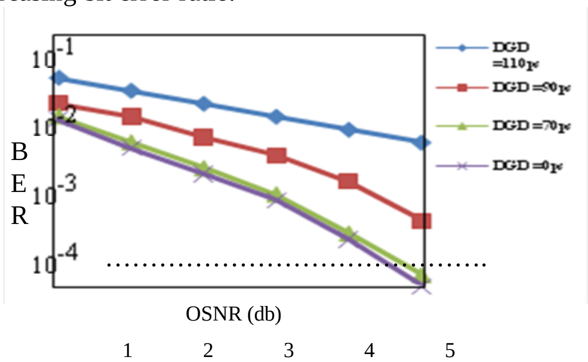


Figure. 6 BER performance (coherent system, 128 subcarriers, 4QAM).

B. SSB Transmission and Direct Detection:

Next the SSB direct detection system was investigated. 128 sub-carriers have been modulated using a 4QAM constellation. As depicted in Fig. 2, after SSB filtering the modulated sub-carriers are located in the upper half of the upper side-band. The symbol duration was not modified; at the receiver an optical filter of 20 GHz bandwidth was used. Like with the coherent receiver DGD induced fading causes performance degradation. Moreover Fig. 6 shows that the direct detection system needs distinctly higher OSNR for reaching a certain BER compared to the coherent receiver [13]. It should be mentioned that this architecture requires half of the optical signal power reserved for the carrier in order to achieve good RX sensitivity. However, this fraction of the signal does not contain information.

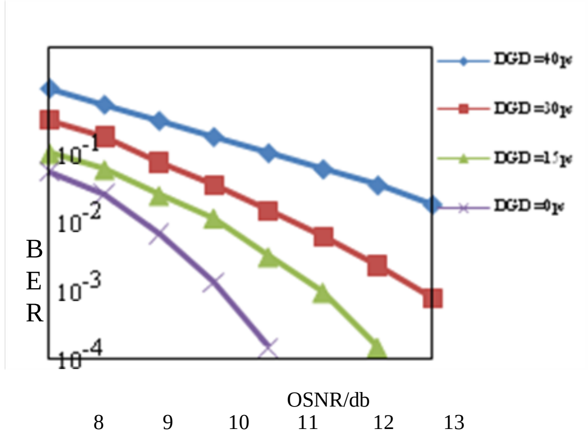


Figure: 7 BER performances (SSB system, 128 subcarriers, 4QAM).

IV. USE OF SENSORS IN THE OPTICAL OFDM

In this paper I have given a basic idea and the concept of optical OFDM.I t is introduced as well as the current research carried out in optical OFDM (OOFDM). The proposed all optical OFDM system is described in Section III. Section IV presents the design considerations that should be followed to calculate the system's parameters. Analysis of the proposed optical OFDM system is presented in this section.

The ISI due to the multipath propagation is a major concern in indoor wireless optical communications. This interference greatly degrades the quality of transmission, and its effects become more severe in case of diffuse links. This is a serious problem, especially in the case of ultra high speed optical wireless LAN such as 1 Gbps or more. To combat the ISI effect, parallel transmission technique is one of the possible solutions [13]. Parallel transmission lowers the data rate per channel, which consequently diminishes the ISI effects. Optical orthogonal frequency division multiplexing is proposed to reduce the effects of ISI in optical communications and thus improve the quality of transmission [14].

In an OFDM system, a serial high data rate data stream is split up into a set of low data rate sub-streams. The total channel bandwidth is divided into a number of orthogonal frequency sub-channels and each of these low data rate sub streams is modulated on a separate sub-channel. The orthogonality is achieved by selecting a special equidistant set of discrete carrier frequencies. It can be shown that, this operation is conveniently performed by the Inverse Fast Fourier Transforms (IFFT). At the receiver, the Fast Fourier Transform (FFT) is used to de-multiplex the parallel data streams. In current research, optical orthogonal frequency division multiplexing is proposed to combat dispersion in optical fiber media [13]. The authors in [14, 15] presented the theoretical basis for coherent optical OFDM systems in direct up/down conversion architecture. In [16], the authors showed that Optical Orthogonal Frequency Division Multiplexing outperformed RZ-OOK transmission in high-speed optical communication systems in terms of transmission distance and spectral

The system starts with the serial high data rate input which then passes to a serial to parallel (S/P) block similar to the conventional OFDM system. The all optical OFDM system differs from the conventional OFDM system in the conversion of the low data rate parallel sub stream into optical signals and performing the IFFT techniques optically rather than electrically. Recent progress of digital signal processing circuit has made it possible to implement the IFFT in wireless communication systems. However, this scheme cannot be applied to the optical communications as the data rate is beyond the digital signal processing speed capabilities.

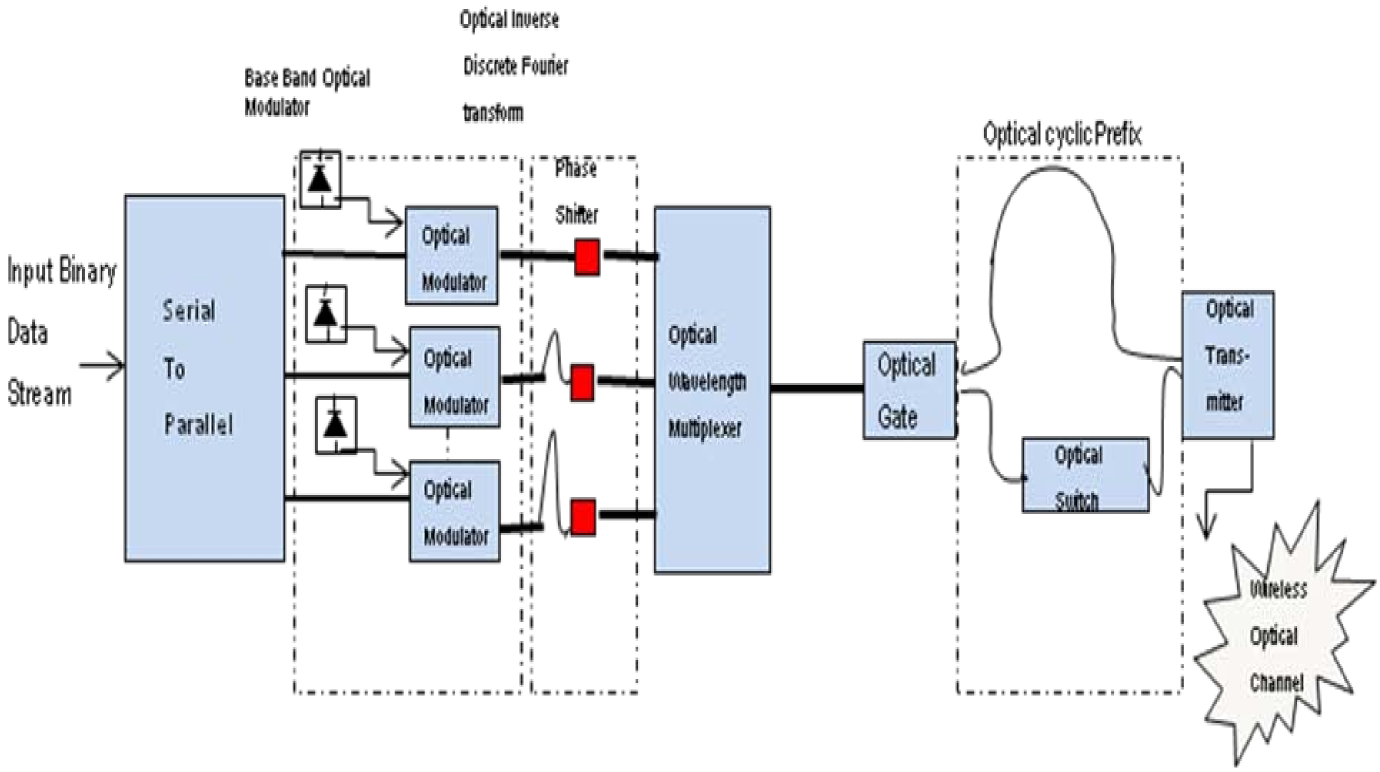


Figure. 8 Optical OFDM Transmitter

The low rate parallel sub stream is converted to an optical signal using electrical to optical conversion. This is followed by modulating each optical sub stream using any type of optical modulation techniques as discussed in [13]. All the optical modulators in Figure 2 have the same optical wavelength and are using the same DFB lasers as light sources. The optical conversion and modulation is called baseband optical modulator.

The baseband optical modulator is followed by an optical IFFT [14], which consists of fibre delay lines and phase shifters. The number of fibre delay lines is equal to the parallel sub streams which also correspond to number of sub-carriers in the conventional OFDM. The delay lines realize orthogonality by having different lengths. The phase shifters implement the different sub-carriers that are orthogonal to each other and thus will be similar to IFFT done by DSP kits.

In conventional OFDM, the output of the IFFT is added together. This is implemented optically using the optical coupler. A cyclic prefix (CP) should be added to overcome the ISI and inter-carrier interference (ICI) [14]. The CP is a crucial feature of OFDM introduced to overcome the multi-path channel effects through which the signal is propagated. The basic idea is to replicate a part of the OFDM time-domain waveform from back to front to create a guard period. The duration of the guard period should be greater than the worst case delay spread of the multi-path environment [15]. This is a challenging technique in optical signals as it is difficult to optically copy and paste. This can be overcome using optical gates and what we called optical cyclic prefix.

The optical cyclic prefix is divided into two branches using an optical coupler; the first branch is a fiber delay line and the second branch is an optical switch.

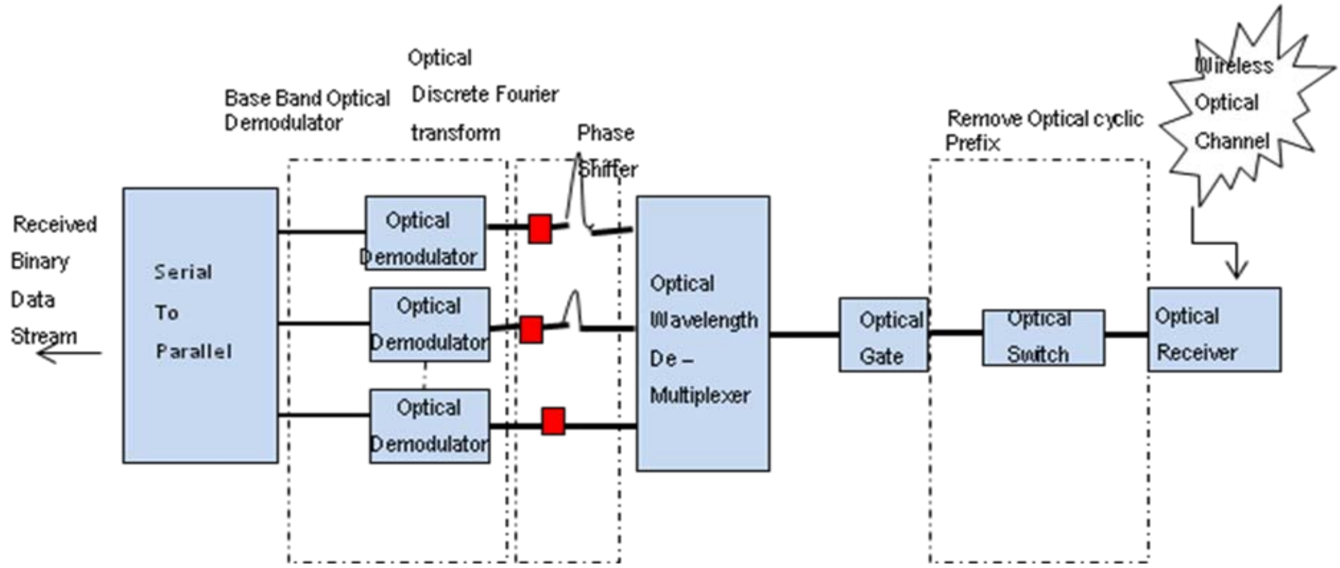


Figure. 9 Optical OFDM Receiver

The optical switch is used to copy the last part of the active ray period and paste it to the front of the optical ray by an optical coupler after it is delayed by a symbol period. The delay is done using the first branch after the coupler. Optical transmitter is used to modulate the OOFDM signal to be suitable for transmission in wireless optical channel [16]. At the receiver side, optical OFDM signal is detected by an optical receiver and then the optical cyclic prefix is removed. The IFFT and optical demodulator are performed to get the corresponding transmitted bit streams the value of non-directed indoor infrared channels ranges from 5 to 20 ns.

The symbol duration Ts, must be set much larger than the guard time. A practical design choice for the symbol time is to be at least five the guard time.

V. CONCLUSIONS

This paper describes the utility of optical devices and optical sensors in the realization of an all optical OFDM System. The analysis of the OFDM Signal and Optical OFDM signal has a great importance in the utilization of these system in optical.

Wireless networks. The proposed power estimated optical OFDM signal could yield the promising results to overcome the multipath effects and Inter symbol Interference for such type of channels .Its applications have been extended from high freq. radio communication to telephone networks, digital audio broadcasting and digital television terrestrial broadcasting . As portable computers and communication terminals become more powerful and more widely deployed, the demand for high speed wireless communication is increasing .The infrared represents an attractive choice for many short range applications. Its advantages are in the terms of the availability of a wide bandwidth that is unregulated worldwide and that can be reused in a very dense manner, immunity to eavesdropping, ability to achieving very high bit rates, low signal processing complexity, potentially very low cost. Optical OFDM has long been studied and implemented to combat the transmission channel impairments. Its applications have been extended from high freq. radio communications to telephone networks, digital audio broadcasting and digital television terrestrial broadcasting

VI. REFERENCES

[1]. A.J. Lowery, L. Du, J. Armstrong: “Orthogonal Frequency Division Multiplexing for Adaptive Dispersion Compensation in Long Haul WDM Systems”, Proc. of OFC 2006, pdp39, Anaheim, USA.

[2]. W. Shieh, and C. Athaudage: „Coherent Optical Orthogonal Frequency Division Multiplexing“,IEE, Electron. Letters, Vol. 42, May 2006.

[3]. [3] M. Mayrock, H. Haunstein: „Impact of Implementation Impairments on the Performance of an Optical OFDM Transmission System“, Proc. Of European Conference on Optical Communications (ECOC), Cannes, France, September 2006.

[4]. M. Seimetz, C.-M. Weinert: “Options, Feasibility, and Availability of 2 x 4 90° Hybrids for Coherent Optical Systems”, J. of Light wave Technology, Vol. 24, pp. 1317-1322, 2006.

[5]. T. Pollet, M. van Bladel, M. Moeneclaey: “BER Sensitivity of OFDM Systems to Carrier Frequency Offset and Wiener Phase Noise”, Trans. on Communications, Vol. 43, pp. 191-193, 1995.

[6]. W. Shieh, W. Chen, R.S. Tucker: “Polarisation mode dispersion mitigation in coherent optical orthogonal frequency division multiplexed systems”, IEE, Electron. Letters, Vol. 42, Aug. 2006.

[7]. I. B. Djordjevic and B. Vasic, “Orthogonal frequency division multiplexing for high-speed optical transmission,” Opt. Express, vol. 14, no 9, pp. 3767–3775, May 2006.

[8]. W. Shieh and C. Athaudage, “Coherent optical orthogonal frequency division multiplexing,” Electron. Lett., vol. 42, no. 10, pp. 587–589, May 2006.

[9]. W. Shieh, X. Yi, and Y. Tang, “Experimental demonstration of transmission of coherent optical OFDM

systems," presented at the Conf. Optical Fiber Communication (OFC), USA, Mar. 2007, Paper OMP2.

[10]. L. Hanzo, M.Münster, B. Choi, and T. Keller, OFDM and MC-CDMA for Broadband Multi-User Communications, WLANs and Broadcasting. New York: Wiley, 2003.

[11]. J. G. Proakis, Digilal Communications, 4th ed. Boston, MA: Mc- Graw-Hill, 2000, ch. 5.

[12]. W. Shieh, X. Yi, and Y. Tang, "Transmission experiment of multi-gigabit coherent optical OFDM systems over 1000 km SSMF fibre," Electron. Lett., vol. 43, no. 3, pp. 183–184, Feb. 2007.

[13]. Ramjee Prasad, Universal Wireless Personal Communication, Artech House Publishers, 1998.

[14]. Magnus Sandell et al, Timing Frequency Synchronisation in OFDM Systems Using the Cyclic Prefa, Div. of Signal Processing, Lulea University of Technology, Sweden.

[15]. Magnus Sandell et al, Low - Complex Frame Synchronisation in OFDM Systems, Div. of Signal Processing, Lulea University of Technology, Sweden.

[16]. Magnus Sandell et al, ML Estimation of Timing and Frequency Ofls et in Multicarrier Systems, Research report, Div. of Signal Processing, Lulea University of Technology, Sweden.

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