MITIGATION OF CHROMATIC DISPERSION BY ALL PASS FILTER

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Abstract:

Dispersion in a single mode fiber is the bottleneck of long haul optical communication systems, which limits the bit rate and repeater-less distance. Chromatic dispersion (CD) of a single mode fiber (SMF) is an important aspect in a long-haul optical communication system**.** Chromatic dispersion leads to inter-symbol interference and degrades the quality of the signal. All-pass filters (APF's) are devices that allow phase correction or equalization without introducing any amplitude distortion. All pass filters (APFs) are used in dispersion compensation which is the foremost requirement in an optical fiber link.

Keywords: Single mode fiber, Chromatic dispersion, all pass filter, Fiber bragg grating

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I.INTRODUCTION:

Optical fiber communication is a way of transmitting the information from one place to another by modulating the light signal with the information signal. Optical fiber communication systems primarily operate at wavelengths near 1.55 μm in order to coincide with the minimum loss point of optical fiber and thereby maximizing the transmission distance.[1] But, at this wavelength, there is a significant amount of group velocity dispersion (GVD) that limits the achievable propagation distance. At the operating wavelength window of 1.55μm, the dispersion in a single mode fiber(SMF) is known as chromatic dispersion(CD) which results in pulse spreading and causes intersymbol interference(ISI)[2].CD is made of material dispersion and waveguide dispersion.The phenomenon of different wavelengths travelling at different speed due to variation of refractive index of the SMF is known as material dispersion.A proportion of the light will also travel in the cladding of the SMF ,which has a different refractive index compared to the core, hence introduces an effect known as waveguide dispersion.[3]

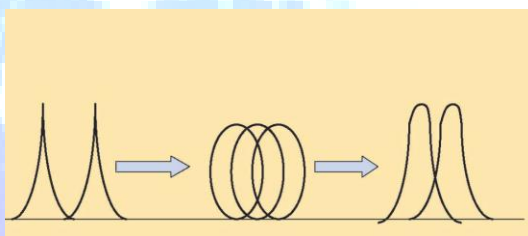

Fig1.Chromatic dispersion effect on optical pulse

The length of the SMF in a high bit rate long-haul optical communication system is limited by the bit rate and the CD [2,4], which can be described by the bit rate length product

$$B^2L=c/(4D\lambda_0^2)$$

where B is the bit rate, L is the SMF length,c the velocity of light, D is the dispersion coefficient and λ_0 the operating wavelength. Therefore doubling the bit rate should reduce the fiber length by a factor of four for a fixed dispersion factor. Therefore in order to realize high bit rate transmission over long distances using the SMF, CD compensation techniques must be employed to overcome signal distortion resulting from dispersion.[5,6]

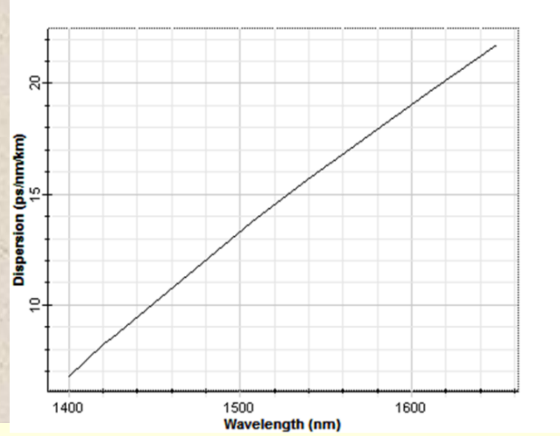

Fig.2 Variation of chromatic dispersion with wavelength

II. CD COMPENSATION:

TECHNIQUES

A number of compensating techniques have been reported in the literature including dispersion compensating fibers (DCFs), Fiber Bragg gratings (FBGs), Electronic Dispersion compensation (EDC) each having its own advantages and disadvantages.

1. Dispersion compensating fibers (DCF):

DCF is a specially designed fiber with negative dispersion, employed to compensate for positive dispersion over large lengths of SMF. DCF typically has a much narrower core than a SMF, causing the optical signal to be more tightly confined and accentuating the problem caused by nonlinear high power effects which results in higher attenuation compared to the SMF [3]. DCF is a loop of fiber which can be inserted at either beginning or end between two optical amplifiers accordingly it is referred to as pre compensation or post-compensation techniques. A third option is to have a DCF at both ends. It is a passive compensation in which loop of fiber having dispersion characteristics that negates the accumulated dispersion of the transmission fiber is inserted at or end of the transmission fiber [7], [8]

2. Fiber bragg grating:

Chirp FBG can compensate CD of a SMF by using the varying distance of grating to delay the faster wavelengths in relation to the slower wavelengths of an optical pulse. By recombining all the wavelengths of an optical pulse at the receiving end, the original optical pulse can be restored. The chirp FBG is limited by its narrow bandwidth and ripple in the opposite GVD. Tunable dispersion is typically achieved by adjusting the chirp on the FBG but causes a large shift in the centre wavelength which is a critical problem [9],[10].

3. Electronic dispersion compensation (EDC):

Since there is direct detection at the receiver, linear distortions in the optical domain, e.g. chromatic dispersion, are translated into no distortions after optical-to-electrical conversion [11],[12]. Due to this reason that the concept of nonlinear cancellation and nonlinear channel modeling attracted increasing attention Electronic compensation circuits can improve system performance at a small cost premium once they have entered large volumes. The simplified equalization circuits feed forward equalizer (FFE) and decision feedback equalizers (DFE) [11],[13]. All pass filters are linear systems having variable phase response and constant amplitude response. The variable phase response of the APFs makes them to be used as the phase equalizers to compensate the chromatic dispersion.

III.ALL PASS FILTER:

The dispersion compensation using digital filters called all pass filters is the most effective way of compensating it. It is a new class of digital filters implemented in the optical domain called all pass filters. All pass filters are lossless filters which offer the flexibility to tune a desired phase response arbitrarily close by increasing the number of stages keeping magnitude response of a system unchanged. All pass filter (APF) is known as phase equalizer because the phase of a signal can be adjusted by APF without introducing any amplitude distortion The design of an optical all pass filter (OAPF) is based on APF. The phase response of OAPF can be designed to cancel the phase delay of SMF which will result in the CD of SMF being cancelled. OAPFs, if designed correctly, are potentially very important devices in optical transmission systems since they can compensate any dispersion in very small structures with very low loss. OAPFs are linear systems which have a unity magnitude response over all frequency. The phase response of OAPFs varies with frequency. An OAPF is a linear system with a unity magnitude response for all frequencies although having a phase response that varies with frequency [14,15,]. The transfer function of an OAPF can be written as [16]

$$H_{OAPF}(\omega)=\exp[\varphi(\omega)]$$

The phase of the OAPF $\varphi(\omega)$ can be made arbitrarily close to any desired phase response. By changing the coefficients of $H_{OAPF}(\omega)$, it is possible to create a group delay with the desired characteristics. These characteristics should be designed such that when the OAPF is placed in cascade with the SMF, the overall resulting group delay response should be zero throughout the frequencies of interest within the system cascade with the SMF, the overall resulting group delay response should be zero throughout the frequencies of interest within the system. The second order all pass filter transfer function can be written in z-domain as

$$H(z)=\frac{r^2-2r\cos\omega_0 z^{-1}+z^{-2}}{1-2r\cos\omega_0 z^{-1}+r^2 z^{-2}}$$

where r is distance of the poles from the origin ($0 < r < 1$) on z-plane and is the angular position ($0 < \omega_0 < \pi$) of the pole on z plane. The r and ω_0 are parameters which are used to control th phase shift of the all pass filter.[16] Optimizing the parameters for r and ω_0 is the key in performing CD equalization with an OAPF. The OAPF is considered to be optimized when the resultant phase response is zero over the frequency band of interest. This is achieved by comparing the phase of the OAPF with the inverse transfer function of the SMF and applying the minimum mean square method.[14,15,17] An improved p-OAPF technique utilizes two OAPFs in parallel to compensate for the effect of CD in the upper and lower frequency bands separately.[18]

IV.RESULTS AND DISCUSSION:

The simulations are carried out at bit-rate of 10Gb/s with an optical source at operating wavelength of 1.55μm.The input data is transmitted through an optical fiber of length 110km.

with dispersion D=17ps/nm-km.The BER is used to assess the performance of digital optical communication systems and can be estimated from the eye pattern [18] given as

$$\text{BER} = \frac{e^{-Q^2/2}}{Q\sqrt{2\pi}}$$

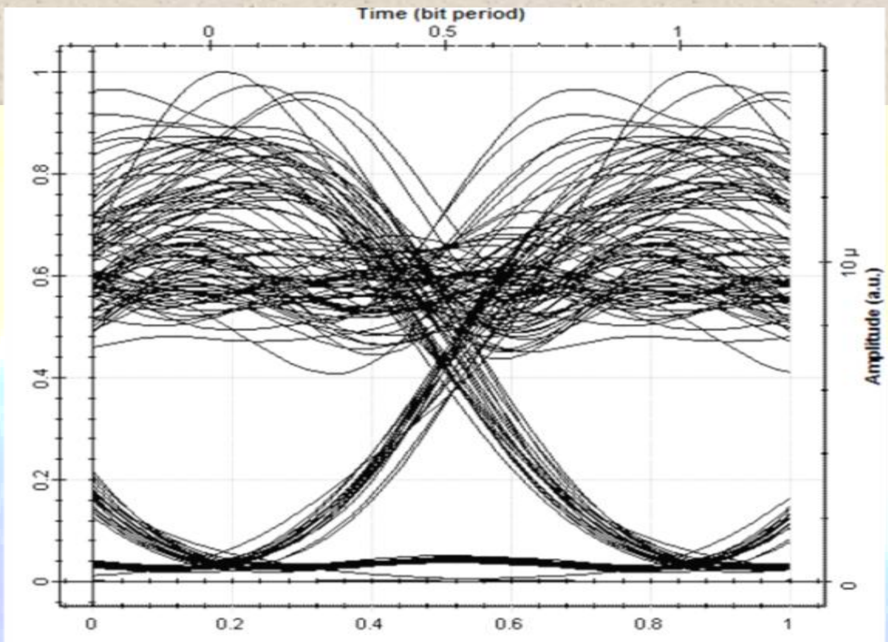

Fig3.Dispersion compensated eye pattern at 110km.

The above figure shows the compensated eye pattern at 110km. The BER for the system of interest shows an improvement of about 11dB.

V.CONCLUSION:

This paper has investigated the performance of all pass filter in a 10 Gb/s optical communication system. Simulation results show that the BER for the system of interest at a length 110km after compensation does not lie completely in error free region(BER< 10^{-9}). However it shows a significant improvement of about 11dB.The all pass filters can be used to provide dispersion compensation at different distances.

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