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A Review Paper on Dispersion Compensation Technique in WDM Optical Networks

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Abstract

It is very well known that when we transmit data or information via wired or wireless channel then definitely some disturbance occurred due to various reasons like atmospheric condition, devices, refraction, diffraction and many more. But if considered about optical fiber then there is distortion in signal which is generally known as dispersion. Dispersion is defined as spreading of pulse in an optical fiber. As a pulse of light travel through a fiber, elements such as numerical aperture (NA), core diameter, refractive index profile, wavelength (ƛ), and laser line width cause the pulse to broaden and one more thing about dispersion is that it increases along the fiber length. There are various types of dispersion occurred in optical fiber and these types also further classified. Now our main task is to compensate various types of dispersion so that there must be a better communication occurred between transmitter and receiver. Therefore dispersion compensation is very crucial feature of an optical transmission system. There are three widely used dispersion compensation techniques i.e. Fiber Bragg Grating (FBG), EDFA and Dispersion Compensation Fiber (DCF). A fiber brag grating (FBG) is one of the most important and applicable component in an optical communication system. The use of chirped FBG has been studied as a dispersion compensator in an optical communication system. Besides this we also analyze how dispersion is compensated in WDM system using different techniques like FBG, DCF, and Digital Filters. The rapid growth in demand for high-capacity telecommunication links, and the speed limitation of single-wavelength links, has resulted in an extraordinary increase in the use of WDM in advanced light wave networks.

Keywords: ***Dispersion Compensation, FBG, DCF, Quality Factor, BER, WDM, EDFA***

1. Introduction

OFC (Optical Fiber Communication) is one of the most important topics of research in today's world communication systems. It reduces the overall net cost of the communication system and also provides a safe way of data transmission at a very high speed [1]. Fiber optic communication is a method of transmitting information from one place to another by sending pulses of light trough optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. The potential bandwidth of optical communication systems is the driving force behind the worldwide development and deployment of light wave system. When an information carrying signal is transmitted at the transmission section of optical fiber communication system some losses occur in optical fiber in form of scattering, scintillations, dispersion, absorption etc. As a result of this the actual information in signal is lost. In single mode fibers (SMF), the main reason for dispersion is chromatic dispersion and polarization mode dispersion. Use of Erbium Doped Fiber Amplifier (EDFA) is one of the ways dispersion can be compensated in an optical fiber [2]. Dispersion compensating fibers (DCF) and Fiber Bragg grating (FBG) are other techniques which can be used for compensation of dispersion in optical fiber link. Electronic Dispersion Compensation is another effective way to compensate dispersion in an optical fiber link.

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2. Literature Survey

In order to improve the overall system performance and reduced as much as possible the transmission performance affected by dispersion, several dispersion compensation techniques were proposed. Among the various techniques proposed in literature, the techniques that appear to hold immediate promise for dispersion compensation can be broadly classified as: Dispersion compensating fibers (DCF), Fiber Bragg grating (FBG) and High order mode (HOM) fiber. The idea of using dispersion compensating fibers (DCF) was proposed in 1980. As the components of DCF are more stable, not easily affected by temperature, wide bandwidth, DCF has become a most suitable method for dispersion compensation. There is a positive second order and third order dispersion in single mode fiber, while the DCF dispersion value is negative. So by inserting a DCF the average dispersion is close to zero. Different Compensation Techniques to compensate Chromatic Dispersion in Fiber Optics" that dispersion compensation is most challenging as well as important aspect to maintain signal to noise ratio in an optical communication. He discussed that Dispersion Compensation Fiber (DCF) is a reliable technology but it also gives high insertion loss as well as introduce some nonlinear distortion when there is high input power. Other dispersion techniques such as electronics dispersion Compensation (EDC), Fiber Bragg Grating (FBG) and Digital Filters are discussed by him. Dispersion Compensation is necessary to reduce losses and coast of the system and can be done through two different methods i.e. DCF and FBG [14-16].

3. Types of Dispersion

Dispersion is defined as spreading of pulse in an optical fiber. As a pulse of light travel through a fiber, elements such as numerical aperture (NA), core diameter, refractive index profile, wavelength (λ), and laser line width cause the pulse to broaden and one more thing about dispersion is that it increases along the fiber length [5]

3.1 Polarization Mode Dispersion

Polarization Mode Dispersion (PMD) occurs due to birefringence along the length of the fiber that causes different polarization modes to travel at different speeds which will lead to rotation of polarization orientation along the fiber [2].

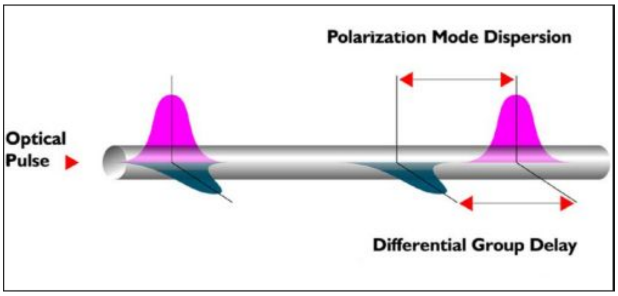

Fig. 1 Polarization Mode Dispersion

3.2 Modal Dispersion

Modal dispersion is defined as pulse spreading caused by the time delay between lower-order modes and higher-order modes. Modal dispersion is problematic in multimode fiber, causing bandwidth limitation.

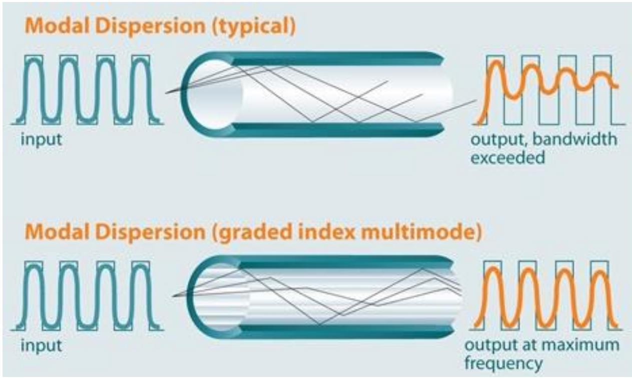

Fig. 2 Modal Dispersion

3.3 Chromatic Dispersion

Chromatic Dispersion (CD) is pulse spreading due to the fact that different wavelengths of light propagate at slightly different velocities through the fiber because the index of refraction of glass fiber is a wavelength-dependent quantity; different wavelengths propagate at different velocities. Chromatic dispersion consists of two parts: material dispersion and waveguide dispersion [5].

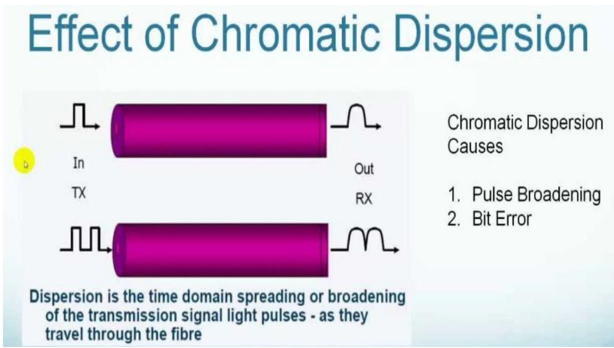

Fig. 3 Chromatic Dispersion

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3.3.1 Material Dispersion

It is due to the wavelength dependency on the index of refraction of glass i.e. refractive index of the core varies as a function of wavelength.

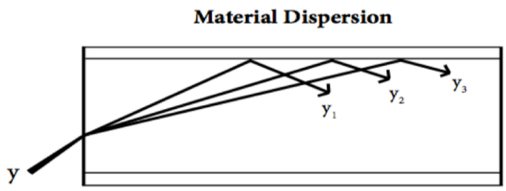

Fig. 4 Material Dispersion

3.3.2 Waveguide Dispersion

It is due to the physical structure of the waveguide. In a simple step-index profile fiber, waveguide dispersion is not a major factor, but in fiber with more complex index profile, waveguide dispersion can be more significant.

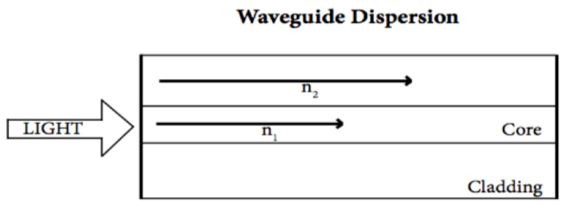

Fig.5 Material Dispersion

4. Dispersion Compensation Technique

4.1 Dispersion Compensation Technique: DCF is considered as one of the most appropriate method to compensate dispersion as it has numerous advantages such as wide bandwidth, large stability, less sensitivity to temperature. It is widely used to compensate dispersion in long-haul optical communication system these days [7]. By connecting DCF to a standard SMF in optical communication system the overall dispersion of system can be reduced to zero. Depending upon the position of DCF in fiber optic link there are three schemes of dispersion compensation: a) Pre-compensation b) Post-compensation c) Symmetrical-compensation

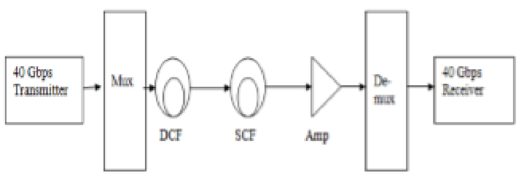

Fig. 6 Schematic of Pre-compensation [1]

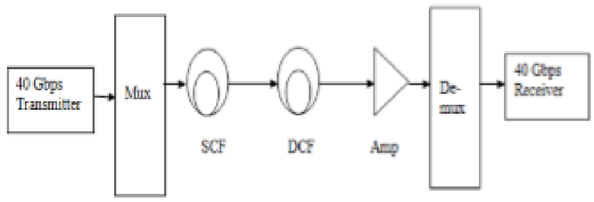

Fig. 7 Schematic of Post-compensation [1]

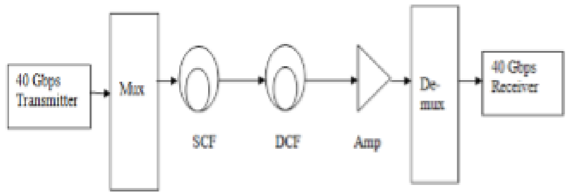

Fig. 8 Schematic of Symmetrical-compensation [1]

4.2 Fiber Bragg Grating: Fiber Bragg Grating (FBG) FBG is very efficient in compensation of dispersion broadening in long haul communication. The basic principle behind the operation of FBG is Fresnel Reflection. In which the light travels between media of different refractive indices which may reflect as well as refract at interface. It is also used as optical filter to block certain wavelengths. The Reflected index will be possible over a particular wavelength.[15] The reflected wavelength (λB), called as Bragg wavelength, given by:

$$\lambda_B = 2ne\Lambda \qquad (1)$$

Here n_e is the effective refractive index,
Λ is grating period
ne depends on wavelengths as well as on the mode of propagated light. So that it is also known as modal index. The wavelength spacing between minima or bandwidth is given by:

$$\Delta\lambda = [2\delta n_0 \eta\ \pi]\lambda_B \qquad (2)$$

Where δn_0 are variations in refractive index
η fraction of power in core.

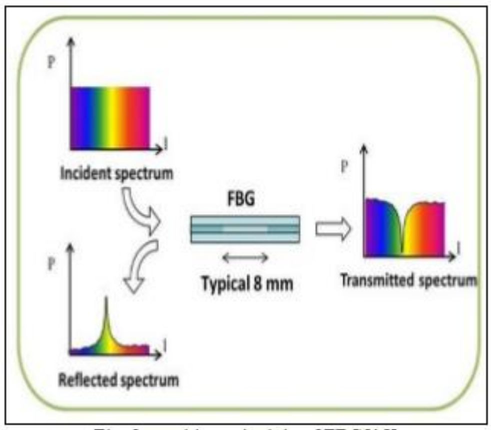

Fig. 9 working principle of FBG

4.3 Electronic dispersion compensation (EDC): Electronic equalization techniques are used in this method. Since there is direct detection at the receiver, linear distortions in the optical domain, e.g. chromatic dispersion, are translated into non linear distortions after optical-to-electrical conversion. It is due to this reason that the concept of nonlinear cancellation and nonlinear channel modeling is implemented. For this mainly feed forward equalizer (FFE) and decision feedback equalizers (DFE) structures are used. EDC slows down the speed of communication since it slows down the digital to analog conversion [3, 6,7]

4.4 EDFA (Erbium doped fiber amplifier): The main goal of every communication system is to increase the transmission distance. Loss and dispersion are the major factors that affect the fiber optic communication system. The EDFA (Erbium doped fiber amplifier) is the enormous change that happened in the optical fiber communication systems; the loss is no longer major factor to restrict the fiber optic transmission. Since EDFA works in 1550 nm wave band, the average Single Mode Fiber (SMF) dispersion value in this wave band is very big, about 15-20ps / (nm.km-1). So, the dispersion is the major factor that restricts the long distance fiber optic communication [3].

5. Conclusions

In this paper it is concluded that during data transmission through optical fiber there are various types of dispersion occurred for example modal, chromatic and polarization dispersion. As we know these dispersion are not beneficial for our transmission so we have to remove these so that communication between transmitter and receiver side would be successful so that there are some technique which we have to use to compensate the dispersion and some of technique are as: EDFA, DCF, FBG and EDC. There are various parameters which we have to analyze during our research work.

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