A Paper Based on Various Dispersion Compensation Techniques

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Abstract— This paper is based on the improvements that are being put in process for fiber developments. A long distance communication, requires maximum bandwidth, minimum worsening of signal and minimum attenuation. Attenuation is no longer an issue in case of optical amplifiers. But dispersion still proves out to be a problem. With Dispersion optical fiber's performance detriorates. Research was carried on how dispersion can be compensated. Using two techniques DCF(Dispersion Compensation Fiber) and FBG (Fiberbragg grating) dispersion can be made less affective in fiber communications. EDFA amplifiers have boosted the capacity of existing systems that's why they are used in the link. Simulation software is a very fast, adequate and economical way to design and analyze fiber optical systems.
Keywords: Attenuation, Dispersion, FBG, DCF, EDFA, Fiber Optical Systems

I. INTRODUCTION

Single Mode cable is a single stand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode Fiber with a relatively narrow diameter, through which only one mode will propagate. Carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. Synonyms monomode optical fiber, single-mode fiber, single-mode optical waveguide, unimode fiber. Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode. The small core and single lightwave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type. Single-mode optical fiber is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest typically 1300 to 1320nm.

Intermodal dispersion is absent, as energy of the injected pulse is transported by simply in single mode. whereas, Pulse broadening does not vanish altogether. The Group velocity associated with the fundamental mode is frequency dependent due to the chromatic dispersion. Different spectral components of the pulse travel at slightly different group velocities, knows as group- velocity dispersion (GVD), intramodal dispersion.

In single mode fiber, we site no presence of intermodal dispersion yet material dispersion exists but is very small

Dispersion is viewed as pulse spreading in an optical fiber. As a pulse of light enters and spreads through a fiber components, for example, numerical aperture, core diameter, refractive index profile, wavelength, and laser line width make the pulse widen. Dispersion grows (increase) along the fiberlength.

Intersymbol Interference (ISI) is the major impact of dispersion on the performance of a fiber optic Communictions. Intersymbol interference happens when the pulse spreading caused by scattering causes the output pulse of a framework to overlap, rendering them undetectable. It is a form of distortion of signals in which one symbol interferes with subsequent symbols, thus causing successive symbols to “blur” together. Dispersion is classified as under:

- Modal dispersion and
- Chromatic dispersion and
- Polarization mode dispersion.

A. *Modal Dispersion*

Modal dispersion is a distortion mechanism occurring in multimode fibers and other waveguides, in which the signal is spread in time because the propagation velocity of the optical signal is not the same for all modes.

It causes pulses to spread out as they travel along the fiber,the more modes the fiber transmits, the more pulses spread out. The arrival of different of the light at different times is called Modal dispersion.

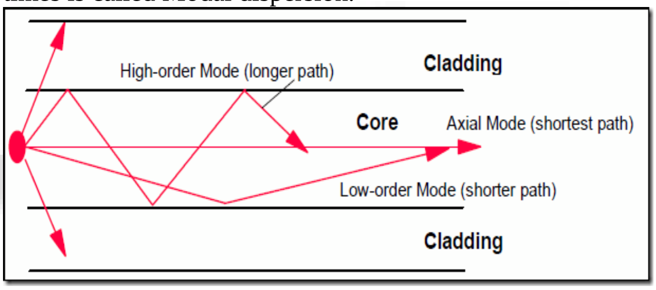
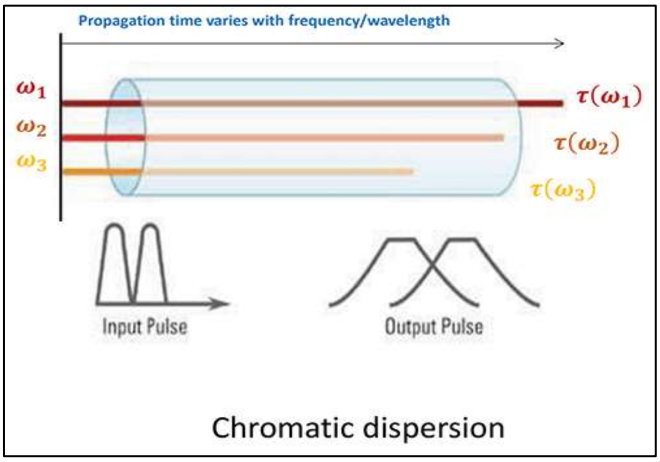


Fig. 1: Modal Dispersion

B. *Chromatic Dispersion (CD):*



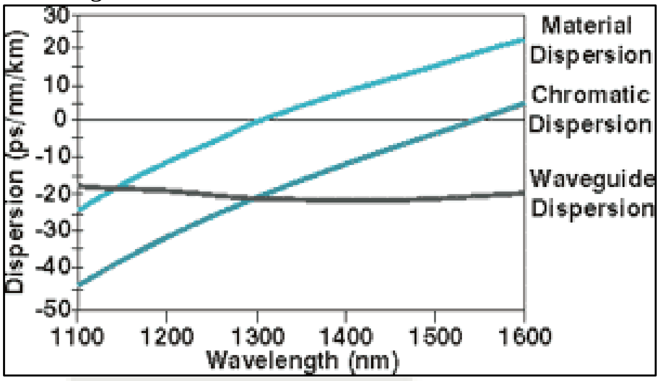
It is associated with wavelength dependent pulse spreading due to the fact that different wavelengths of light propagate at slightly different velocities through the fiber because the index of refraction of glass fiber is a wavelength-dependent quantity; different wavelengths propagate at different velocities. Chromatic Dispersion (CD) that causes pulse broadening depending on wavelength.

Chromatic dispersion causes pulse broadening and Bit errors.

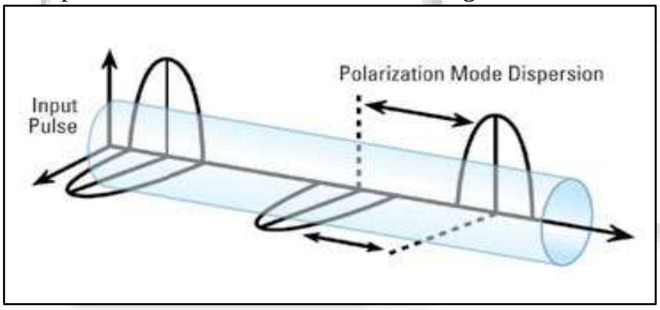
Chromatic dispersion consists of two parts: material dispersion and waveguide dispersion

1) Material Dispersion

Pulse broadening due to material dispersion results from the different group velocities of the various spectral components launched into the fiber from the optical source. It occurs when the phase velocity of a plane wave propagating in the dielectric medium varies nonlinearly with wavelength, and a material is said to exhibit material dispersion when the second differential of the refractive index with respect to wavelength is not zero.



Dispersion characteristics of standard single-mode fiber.



Polarization Mode Dispersion

2) Waveguide Dispersion

It occurs when light travels with in an enclosed medium. Waveguide dispersion depend on the refractive index profile and can be changed. It can be used to produce dispersion-decreasing fibers in which GVD decreases along the fiberlength.

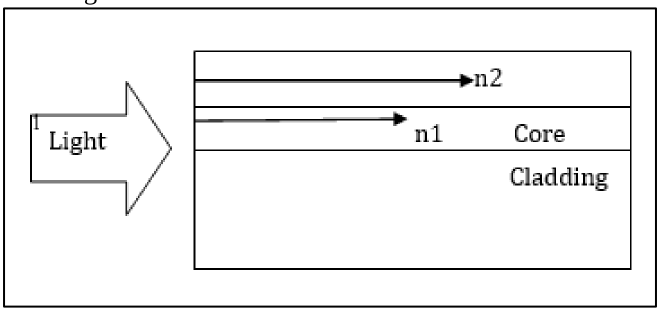


Fig. 4: Waveguide Dispersion

C. Polarization Mode Dispersion (PMD)

It happens because of birefringence along the length of the fiber that makes diverse polarization modes go at various rates which will prompt revolution of polarization introduction along the fiber.

II. DISPERSION COMPENSATION TECHNIQUES

DCF (Dispersion Compensation Fiber)

Excess of dispersion in a system leads to power penalty and poor quality of service. As the needs of users increase ,more bandwidth is required and dispersion limits bandwidth in optical fibers.

In Chromatic dispersion, it gives an opportunity to compensate for dispersion along the entire span of the fiber-optic link. In DCF the positive dispersion can be compensated by inserting a piece of fiber with a negative dispersion characteristic so that the total dispersion of the link will be almost zero.

Fig. 5: Dispersion Compensating Fiber

DCF compensation needs very high negative dispersion coefficient with DCF's to compensate dispersion in a narrow band frequency.

There are three schemes in Dispersion Compensation Fiber

1) Pre Compensation

In Pre compensation, DCF is placed before SMF. The designing consists of DCF, EDFA and SMF. Purpose of EDFA after DCF is that it provides periodic amplification. Dispersion Parameter is expressed in ps/nm/km and is in negative.

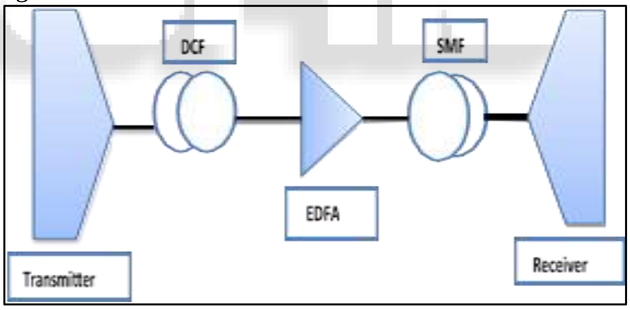


Fig. 6: Pre Compensation

2) 2 Post Compensation

As dispersion causes pulse broadening and pulse distortion. Another compensation is post compensation in which SMF(single mode fiber) is placed before DCF.

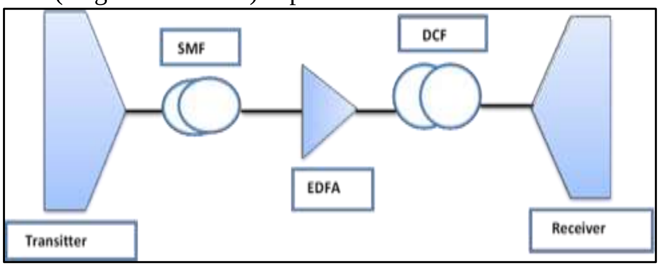


Fig. 7: Post Compensation

B. Symmetric Compensation:

In symmetric compensation, DCF is placed before and after the standard fiber.

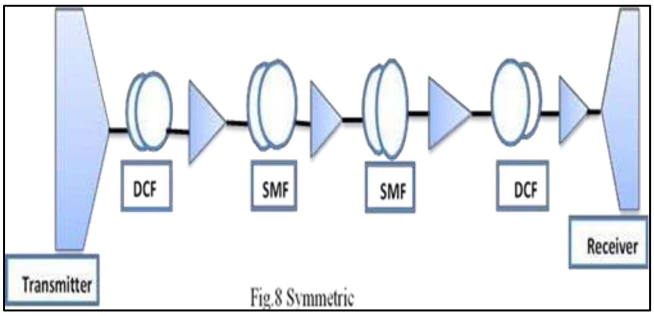


Fig. 8: Symmetric Compensation

III. FIBER BRAGG GRATING

A. Fiber Bragg Grating (FBG)

It is the another dispersion compensation technique. It acts as an optical filter because of existence of a stop band. Fiber bragg grating acts as a reflection filter. FBG is a type of distributed Bragg reflector which reflects a particular wavelength of light and transmits all others. A Fiber Bragg Grating[2] is either used as an inline optical filter to block certain wavelength or as a wavelength specific reflector. There is a periodic variation of refractive index in Bragg grating within the propagating medium .FBG provides a wide variety of applications, such as notch filtering, dispersion compensation, channel equalization, real time signal processing, etc.in optical communications.

FBG is used in two configuration:

1) Pre Compensation

It defines when the FBG is placed at the starting of optical link and before amplifier. Following figure describes the concept of pre compensation.

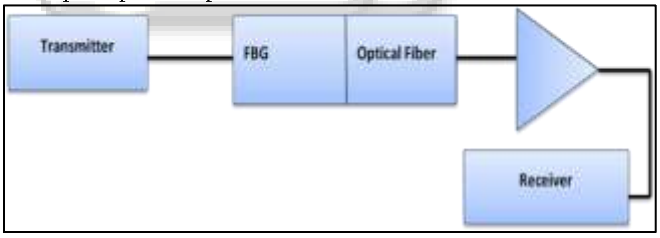


Fig. 9: Pre Compensation

2) Post Compensation

It defines the situation when FBG s placed at the end of optical link. Following figure describes the post compensation.

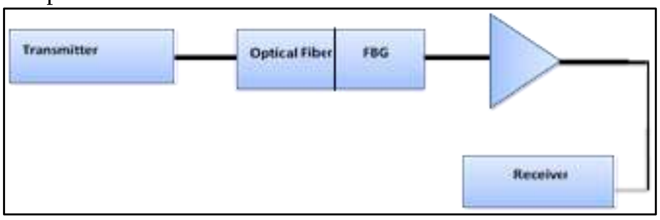


Fig. 10: Post Compensation

3) EDFA (ERBIUM-DOPED FIBER AMPLIFIERS)

Erbium-Doped Fiber Amplifier (EDFA) is an optical amplifier used in the C-band and L-band, where loss of telecom optical fibers becomes lowest in the entire optical telecommunication wavelength bands. Invented in 1987, EDFA is now most commonly used to compensate the loss of an optical fiber in long-distance optical communication. Another important characteristic is that EDFA can amplify multiple optical signals simultaneously, and thus can be easily combined with WDM technology.

EDFAs are used as a booster, inline, and pre-amplifier in an optical transmission line, as schematically shown in Figure 2. The booster amplifier is placed just after the transmitter to increase the optical power launched to the transmission line. The inline amplifiers are placed in the transmission line, compensating the attenuation induced by the optical fiber. The pre-amplifier is placed just before the receiver, such that sufficient optical power is launched to the receiver. A typical distance between each of the EDFAs is several tens of kilometers. The EDFA is the enormous change that occurred in the optical fiber communication systems; the loss is no longer major factor to restrict the fiber optic transmission. Gain of an EDFA depends on a number of parameters such as erbium-ion concentration, amplifier length, core radius, and pump power. Performance of EDFA depends on the signal wavelength since both the noise figure and the pump power required to achieve transparency change with the signal wavelength.
communication

IV. COMPARISON BETWEEN DCF ANDFBG

Characteristics	DCF(Dispersio n Compensating Fiber)	FBG (Fiber Bragg Grating)
Attenuation	0.8 dB/km	0.2 dB/km
Insertion Loss	High	Low
Non Linear effects	some limitations	No
Construction	Complex	Simple
Overall Cost	High	Low
Bandwidth	Wide band,20nm	Narrow band, 0.1- 5nm

Table 1: Comparison between DCF & FBG

V. CONCLUSION

By choosing an appropriate wavelength that is equal to the zero dispersion wavelength, chromatic dispersion can be compensated. Also, Polarization mode dispersion becomes bandwidth limited as there is no means to eliminate PMD. For communication over longer distances, dispersion compensation is vital. As it is necessary to reduce losses and cost of the system. It is concluded that Dispersion compensation fiber and fiber bragg grating techniques are used as per requirement of the system. Also, EDFA is used as an amplifier in the link as it can operate in both the C band as well as in L band and boost the system performance. As insertion loss is less in FBG and it also helps in reducing cost of the system while DCF increases total losses and cost of the system.

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