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ANALYSIS OF DISPERSION COMPENSATION FIBER IN LONG DISTANCE FIBER OPTIC TRANSMISSION SYSTEM

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ABSTRACT

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In long haul fiber optic communication system, dispersion is the most important factor that limits the system performance greatly. Compensation of dispersion in a single mode fiber (SMF) around 1.55 µm operating wavelength can be achieved by specially designing fiber. This type of fiber is called as dispersion compensating fiber (DCF). In this paper, DCF were analyzed for the effects of dispersion and attenuation to obtain the equation of transfer function for each effect in terms of fiber length, dispersion co-efficient, operating wavelength, frequency, number of connector etc in the fiber. By using these equations, DCF model have been simulated using Matlab. Then the outputs of fiber have been taken, analyzed and evaluated for different values of dispersion co-efficient, attenuation co-efficient, number of connectors etc. The results of this research paper indicate that the desired optimized performance of DCF can be achieved by choosing appropriate values of different parameters of DCF.

Key words: *single mode fiber, dispersion compensation fiber, transfer function, nonlinear effects*

INTRODUCTION

Information transmission over an optical fiber has become one of the most important communications systems. As the single mode fiber (SMF) transmission systems evolved to longer distances and higher bit rates, the linear effect of fibers, which is the attenuation and dispersion, becomes the important limiting factor (Singh and Singh, 2012). In Wavelength Division Multiplexed (WDM) systems, a single fiber can carry separate wavelength signals or channels simultaneously (Uddin and Saha, 2010). As the capacity of fiber transmission systems increases, the spacing between WDM channels needs to decrease to make optimal use of limited optical low loss spectrum window (Kumar *et al.* 2012). The high power values as well as the less spacing between channels increase nonlinear crosstalk between the channels due to the nonlinear properties of the transmission fiber. At higher bit rates and distances, the nonlinear effects in the fiber begin to present a serious limitation. High speed transmission over SMF at 1.55 µm suffers severely from nonlinearity and dispersion (Singh and Singh, 2012).

At long distances, the link losses mainly connector attenuation also degrades the system performances. Thus at high capacity, bit rate, power and distance, the fiber linearity, non-linearity effects and connector attenuation affect the transmitting pulse so that the performance of SMF degrades significantly.

Dispersion is defined because of the different frequency or mode of light pulse in fiber transmits at different rates, so that these frequency components or models receive the fiber terminals at different time. It can cause intolerable amounts of distortions that ultimately lead to errors. Without dispersion compensation, each symbol would be broadened so much that it would strongly overlap with a number of neighbored symbols; significant inter-symbol interference can strongly distort the detected signal (Kumar *et al.* 2012). Therefore, it is essential to compensate the dispersion before detecting the signal. In order to improve overall performance of the system and reduced as much as possible the transmission performance influenced by the dispersion.

The success of high bit rate long haul optical transmission networks depends upon how best the linear and nonlinear effects are managed. The nonlinear effects can be managed through proper system design. In some circumstances when the nonlinearity and dispersion are considered together, the nonlinearity could counteract the dispersion (Singh and Singh, 2012). Dispersion management scheme is used for upgrading the existing SMF communication systems. The use of DCF is an important method for dispersion compensation and to upgrade the already installed links of SMF. In DCF, dispersion is compensated and non-linearity cannot dominant. Dispersion compensation fiber has the opposite dispersion fiber being used in a transmission system. It is used to nullify the dispersion caused by that fiber. Several dispersion compensation technologies were proposed. Compensation of dispersion at wavelength around 1.55 µm in a SMF can be achieved by specially designed fibers whose dispersion co-efficient is negative and large at 1.55 µm. These types of fibers are known as DCF (Gowar 1984; Nilsson-Gistoik 1994; Ahmed 2007).

This paper is organized as follows. After introduction, the equations of dispersion and attenuation for DCF have been discussed. Then the simulation model of DCF is shown. Numerical values of different parameters for DCF are shown in Table 1. After that the results are discussed. Finally the conclusions are drawn.

DCF ANALYSIS FOR THE EFFECT OF DISPERSION AND ATTENUATION

In this section, the DCF has been analyzed in presence of dispersion and attenuation effect. The transfer function of dispersion effect can be expressed as (Saleh 2004).

$$H(f) = e^{-j\pi D\lambda Lf} \quad \text{...}(1)$$

Where j is complex vector, D represents the dispersion coefficient, λ represents the operating wavelength, L represents the length of the fiber while f represents the frequency of the optical carrier and its sidebands.

The connector loss for optical link can be calculated by (SoftTDMv1.5)

$$A_C = 10^{\left[\frac{\alpha N}{10}\right]} \quad \text{...}(2)$$

Where α and N are the attenuation coefficient and number of connectors respectively.

SIMULATION MODEL FOR DCF FIBER

By Matlab simulink of equations (1) and (2) the model of DCF is obtained as shown in Fig. 1. Gaussian pulse is used as the input signal. The output is taken after DCF is called DCF signal with negative dispersion effect.

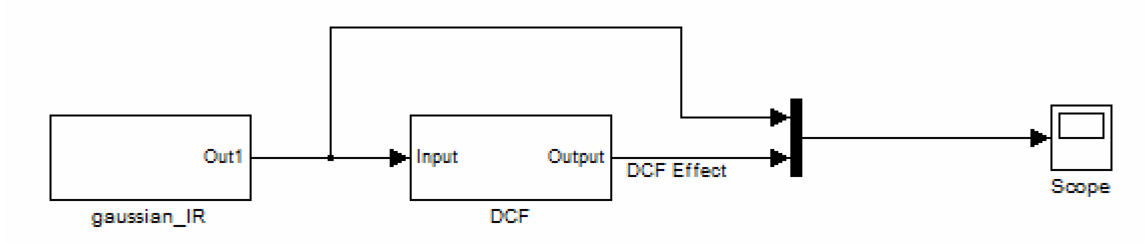

Fig. 1. Simulation model of DCF Fiber

Table 1. Numerical values of different parameter for simulation

Parameters(unit)	Numerical values
Dispersion co-efficient, $D(ps/km^{*}nm)$	Varied
Operating wavelength, $\lambda(nm)$	1550
Frequency of optical carrier, $f\,(Hz)$	$1.93414489 \times 10^{14}$
Length of the fiber, $L(m)$	Varied
Attenuation co-efficient, α (dB/km)	Varied
Number of connector, N	Varied

RESULTS AND DISCUSSION

The performances of the DCF have been taken, evaluated and analyzed in terms of output pulse power. The input Gaussian pulse and the output pulse of DCF for number of connectors $N = 2$ and $N = 4$ are shown in figure (2) and figure (3) respectively.

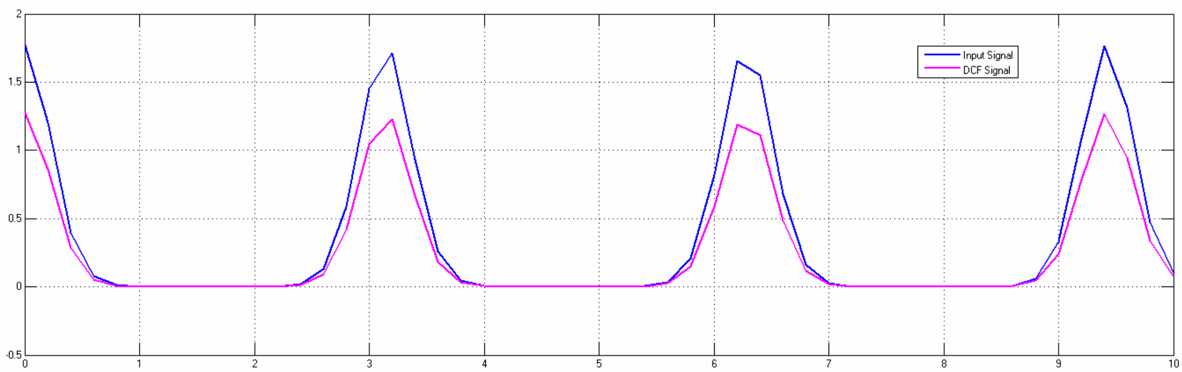

Fig. 2. Input pulse and the DCF pulse for number of connector, $N = 2$.

From figure (2), it has been observed that the peak power of input is 1.75, while the peak power of output is 1.25. Thus the amplitude of output pulse is decreased for the effects of dispersion and attenuation in DCF.

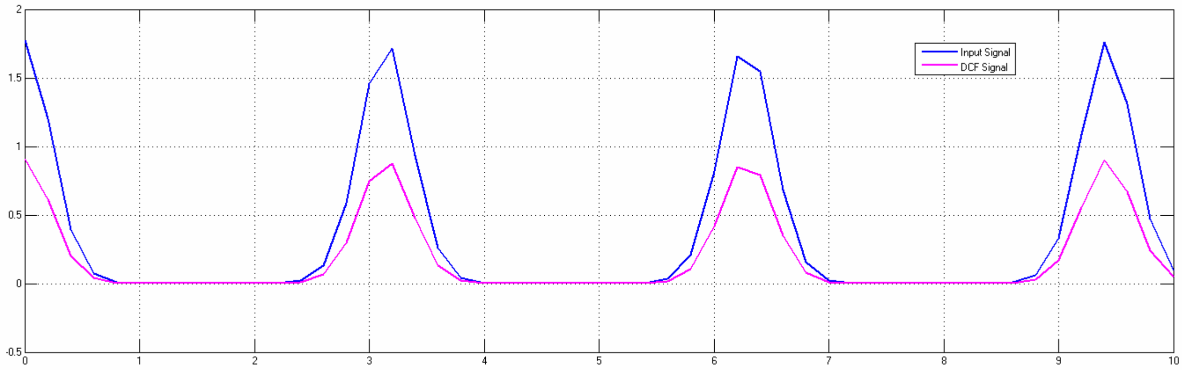

Fig. 3. Input pulse and the DCF pulse for number of connector, $N = 4$.

It has been observed from figure (2) and figure (3) that for $N = 2$. the peak power of output is 1.25, while at $N = 4$ the peak power of output signal is 0.8. It is clear that as the number of connector N increases, the output power decreases in DCF fiber.

The input and output pulses for attenuation co-efficient, $\alpha = 0.2 dB/km$ and $\alpha = 0.75 dB/km$ have been visualized in figure (4) and figure (5) respectively.

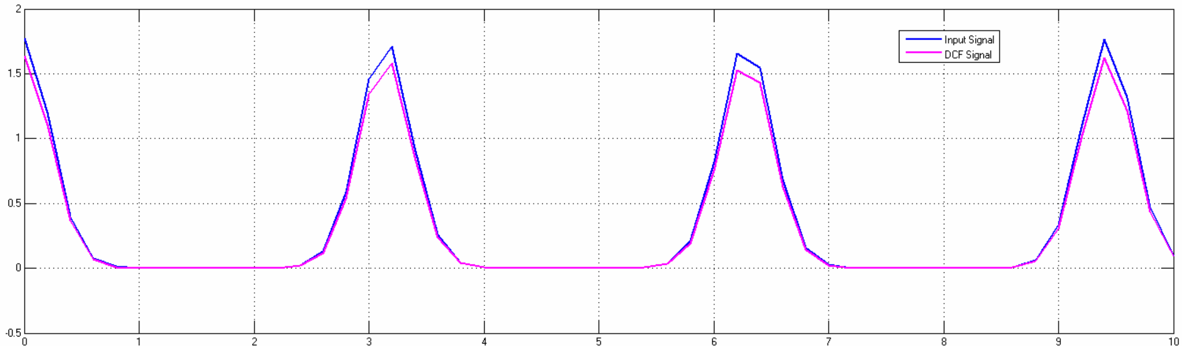

Fig. 4. Input pulse and the DCF pulse for attenuation coefficient $\alpha = 0.2 dB/km$.

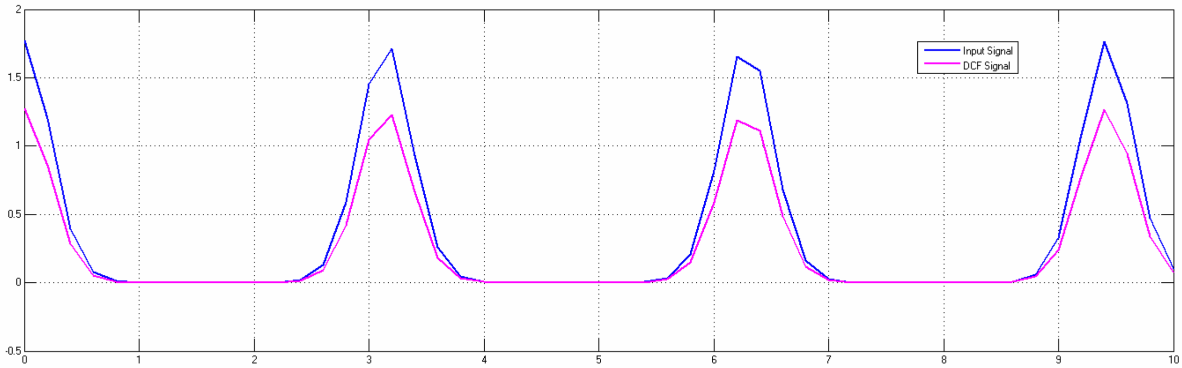

Fig. 5. Input pulse and the DCF pulse for attenuation coefficient $\alpha = 0.75 dB/km$.

It has been observed from figure (4) and figure (5) that for $\alpha = 0.2 dB/km$ the peak power of output is 1.6, while at $\alpha = 0.75 dB/km$ the peak power of output is 1.25. Thus the increasing of attenuation coefficient α of DCF decreases transmitting signal power.

The input and output pulses for dispersion coefficient $D = -400\, ps/km*nm$, fiber length $L = 2km$ and $D = -548\, ps/km*nm$, $L = 1.44km$ have been visualized in figure (6) and figure (7) respectively.

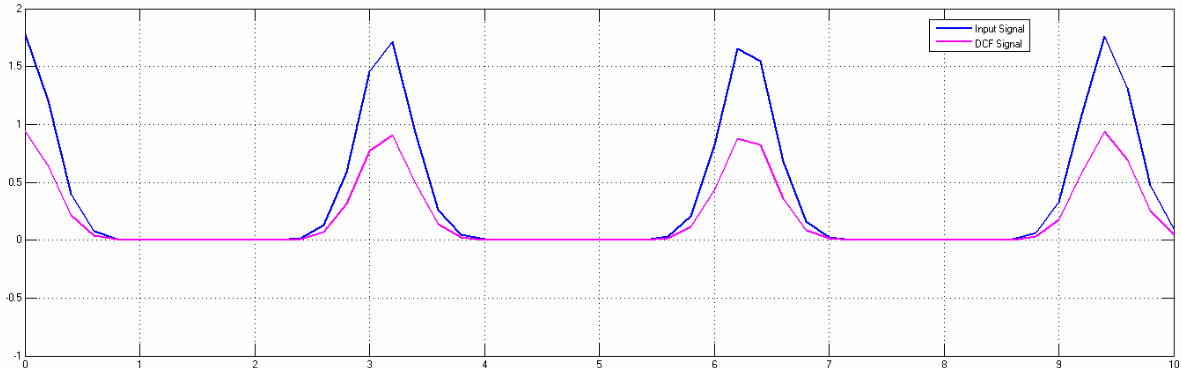

Fig. 6. Input pulse and the DCF pulse for dispersion coefficient –400 ps/km*nm and fiber length 2 km.

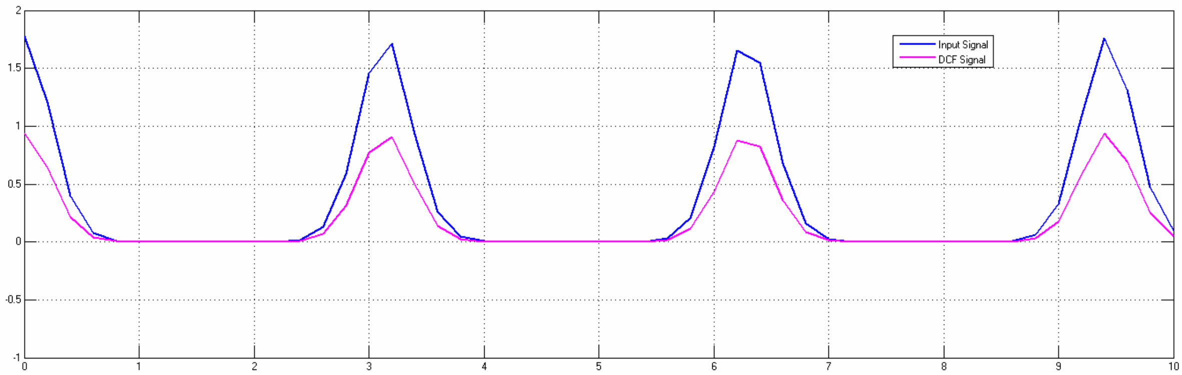

Fig. 7. Input pulse and the DCF pulse for dispersion coefficient –548 ps/km*nm and fiber length 1.44 km

It has been observed from figure (6) and figure (7) that if the negative value of dispersion coefficient D is increased from $400\, ps/km*nm$ to $548\, ps/km*nm$ and the fiber length L is decreased from $2km$ to $1.44km$, then the power of output remains same and is 0.9. Thus, in presence of higher dispersion coefficient, the smaller fiber length will be required to obtain particular output in the dispersion compensating fiber.

CONCLUSION

A theoretical analysis of dispersion compensation fiber has been carried out to obtain expressions of transfer function due to effects of dispersion and attenuation in terms of fiber length, dispersion parameter, operating wavelength of fiber, frequency, number of connector etc. Then dispersion compensation optical fiber has been simulated by using these expressions. While analyzing, it is found that the amplitude of output pulse is decreased for the effects of dispersion and attenuation in DCF. We also noticed that the power of output signal decreases with increasing attenuation coefficient. It is investigated that as the number of connector increases, the power of output signal of DCF decreases. It is also observed in presence of higher dispersion coefficient, the smaller fiber length will be required to obtain particular output in the dispersion compensating fiber. The results of this research paper indicate that the desired optimized performance of DCF can be achieved by choosing appropriate values of different parameters of DCF.

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