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# Multistage Amplified and Dispersion Compensated Ultra-long Haul DWDM Link with High OSNR

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***Abstract*—A multistage amplified and dispersion compensated Dense Wavelength Division Multiplexed (DWDM) ultra-long haul optical network is proposed, with a capacity of 8×10Gbps. The network dispersion is mitigated in multiple spans to make ultra-long haul communication possible. Multistage amplifiers allow signal amplification in intervals, making the system less prone to non-linearity. The position and gain of amplifiers are optimized thoroughly, to attain a high OSNR (Optical Signal to Noise Ratio). The Q-factor penalty and power penalty of the system are investigated analytically. All the DWDM limitations are taken care of while designing the network. Finally, the propagation distance of 700km, with a Quality factor of 7.06, permissible BER and a commendable OSNR, is achieved.**

***Keywords—Wavelength Division Multiplexing (WDM), Conventional Single Mode Fiber (CSMF), Optical Signal to Noise Ratio (OSNR), Power Penalty, Raman Scattering, Dispersion Compensation Fiber (DCF).***

## I. INTRODUCTION

Over the past decade, the demand for optical fiber communication (OFC) plunged due to its numerous advantages. However, the system dispersion limits the high data rate transmission for long-haul optical links [1,2] and needs to be managed by suitable dispersion compensation schemes [3]. The dispersion results in pulse broadening, owing to the bit pulses overlapping each other, resulting in inter-symbol interference (ISI) [3]. The pulse broadening is a function of length in addition to the dispersion, which distorts all types of signals [3]. Although a good number of papers report research regarding dispersion compensation [2,4-8], the efficient utilization of the data-carrying capability of optical networks is still confined. DWDM has made high-capacity wavelength services possible by multiplying the bandwidth of a single optical fiber [2] which multiplexes more than 18 channels through a fiber. Although DWDM increases the transmission capacity of the optical transmission system without using additional SMF, pulse spreading due to dispersion still limits the system performance by introducing cross-talk.

Most previously reported works have used DCF and Fiber Bragg Grating (FBG) for dispersion compensation. FBG works as a Band-stop filter and offers reliable dispersion compensation to a particular frequency component [5, 8]. On the contrary, DCF offers uniform dispersion compensation to multiple spectral components and offers upgradability to already installed links [9].

The proposed work presents an ultra-long haul 8×10Gbps multistage amplified DWDM optical network, wherein multiple spans of dispersion compensation module are used in periodic compensation mode for dispersion compensation in the channel. The link dispersion mitigated in intervals makes ultra-long-haul communication possible. All the DWDM link limitations are considered carefully, like the low effective area of DCF that increases non-linearity across DCF, cross talk due to Raman scattering in channels, and high attenuation across DCF. The maximum propagation distance of 700km with good Q-factor value, limited BER and commendable OSNR, is achieved. Further, the link power factor penalty and the Q-factor penalty are investigated analytically.

The paper is catalogued orderly as follows. Section 2 presents the theory with the principle of operation, mathematical analysis and the limitations in the DWDM network. Section 3 represents the simulation set-up of the proposed system model in detail. Results (with discussion) are stated in Section 4. Eventually, the conclusion is epitomized in Section 5.

## II. THEORY

In Conventional Single Mode fibers (CSMF), Chromatic-dispersion leads to the pulse broadening of the optical signal dispatched into the waveguide. With the increasing transmission distance the pulse broadening increases and leads to ISI [3, 8, 10, 11]. However, CSMF has the benefit that intermodal dispersion doesn't occur in it [3, 10, 11]. For externally modulated sources (like in WDM systems), chromatic dispersion limits the maximum transmission distance to 30km only at the bit rate of 10 Gbps [11].

Designing an optical filter for dispersion management in the optical link is challenging and needs an alternative solution. DCF offers flexibility for the design of desired transfer functions [11]. DCF is analogous to SMF in structure, with the difference in doping level. The DCF core is doped with $GeO_2$ at a very high rate, inducing high negative dispersion. However, the DCF negative dispersion cannot be increased beyond its optimal range (-70 to -80 ps/nm/km), as it results in higher losses [12]. As the core area of the DCF is small (2-3μm) as compared to the SMF core area (8-10.5μm), the DCF losses are higher (0.35dB/km) [13]. The effective fiber area is 35.3μm2 (1/2.5 of that of SMF), exhibiting higher non-linear effects [14]. Further, long-haul optical links demand higher length DCF to compensate for higher dispersion arising in the propagating channel, which in turn increases the cost associated. However, DCF offers the upgrading of old fiber links or WDM systems smoothly [11].

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