Design of High Speed Optical Fiber Cables and Transmission Techniques in Advanced Optical Networks

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Abstract

In the present paper, design of high velocity fiber-optic communication networks with ultra wide-dense wavelength division multiplexing (UW-DWDM), space division multiplexing (SDM) and optical transmission techniques is presented. All connects in the (SDM) are split into subgroups of various chemical and geometrical characteristics .The parameters have been designed at: i) Δn, the relative refractive index difference for both the core and also the clad, ii) x%, the percentage of doping in silicon material by Germanium material. The Δn and x% parameters are also preserved during their technological boundaries of attention. UW-DWDM has 1200 channels that transferred at the fiber-optic wavelengths from 1450 nm up to 1650 nm within 140 connects from UW-SDM wherever every connect is prepared to own the same compressed chromatic dispersion. From this technique, it is noticed that the connect design parameters suffer more nonlinearity with the number of connects. So, two different propagation techniques have been used to investigate the transmitted bit-rate as a criterion to enhance the system performance. The first technique is Soliton propagation, where the control parameters lead to equilibrium between the pulse spreading due to dispersion and the pulse shrinking because of nonlinearity. The second technique is the maximum time division multiplexing (MTDM) technique where the parameters are adjusted to lead to minimum dispersion. Two cases are investigated; no dispersion cancellation and dispersion cancellation. The investigations are conducted over an enormous range of the set of controlling parameters. Thermal effects are considered through three basic quantities, namely: the transmission bit rate, the dispersion characteristics and the spectral losses.

Keywords: UW-DWDM, optical soliton, UW-SDM, chromatic dispersion, MTDM.

1. Introduction

The inter-symbol interference results from the conjoint influences of laser chirp and the chromatic dispersion that causes great performance deterioration. The utilization of zero-dispersion wavelength around 1550 nm with dispersion-shifted fiber (DSF) is one of the reforms for this problem [1].

Optical fiber communication systems are secure better than the electrical systems used widely in the global telecommunication and data rate. Optical communication systems are largely used for advanced communication links of global network and also the major applications of in the area of modern telecommunications, optical sensors, optical devices and integrated optics. The glass fiber optics are used to transfer light from one end to the other with minimum loss. The laser diode in fiber optic communication systems transfer infrared light, unseen to the human eye, as a result of it goes faraway within the optical fiber at those wavelengths. Many countries are utilize optical fiber for Internet connection, telephone telecommunication and Internet protocols. In optical fiber communication system, a large quantity of information can be transferred. Optical fiber communication systems have some of benefits, for example, the bandwidth is wide which leads to large data capacity. The ability to avoid the interference, low losses (0.2 dB/km) which leads to long distance transmission, and this decreases the number of repeaters, improves protection. The signal become more secure and less expensive in contrast to metallic cables [2-7].

When the refractive index with wavelength varies, the laser light pulses will be moved at various velocities. These light waves after some distance in the fiber-optic. Suffer from broadening in the width of these waves with time occur causing raise in the width. This phenomenon of broadening of pulse width is called dispersion. Dispersion of the transferred optical signal lead to distortion for both analog and digital transmission along fiber-optics. Therefore, the dispersion in long distance becomes a large problem, to solve this problem, there are some of methods such as optical solitons [5-6,8]. The soliton pulses are fixed shape and power for balancing between optical fiber nonlinearity with the optical dispersion [9-11].

The rest of this paper is regulated as follows: Part (2) is the fundamental model and analysis of the observed problem, Part (3) explains the acquired results and general discussion, and finally, part (4) briefs the conclusions.

2. Basic Model and Analysis

A. Designed Set of Parameters (x, Δn):

The designed data: The binary glass fiber-optical consists of $[SiO_2(1-x)+GeO_2(x)]$, The optical fiber wavelength domain of interest is $\Delta\lambda = 1.65 - 1.45 = 0.2$ μm where: (1.45 ≤λ, μm ≤ 1.65), The number of channels, N_{ch}=1200 channel (UW-WDM) transferred within (20, or 40, or 60, or …..). The links of fiber- optic, N_L (UW-SDM), the sub-optical windows, where $\delta\lambda = \frac{\Delta\lambda}{N_L}$ and each link possess as sub-optical window of $\{\lambda_i, \lambda_c, \lambda_f\}$.

Thus:

i) λ_i = initial value of suboptical window $= 1.45 + (N_s - 1)\delta\lambda$ (1)

where $N_s = \{1,2,3,\ldots\ldots,N_L\}$ is the order of the link, $\delta\lambda$ is The sub-optical windows as shown above.

ii) λ_f = final value of suboptical window $= 1.45 + N_s\delta\lambda$ (2)

iii) λ_c = is the center of the suboptical window $= 1.45 + (N_s - 0.5)\delta\lambda$ (3)

The total chromatic dispersion coefficient D_t is cast under the form:

$$D_t = D_m + D_{wg} \quad (4)$$

where, D_m is the material dispersion coefficient and D_{wg} is the Waveguide dispersion coefficient [3,13-15].

At any compressed dispersion D_{ts}, and at any λ of the set $\{\lambda_i, \lambda_c, \lambda_f\}$, a set of variables {x, Δn} in is selected parallel process intervals: $0.0 \le x \le 0.2$, $0.001 \le \Delta n \le 0.01$, where Δn and x are varied as the following:

$$x_{new} = x_{old} + \delta x, \quad \delta x = (\text{range of } x)/1000 \quad (5)$$

$$\Delta n_{new} = \Delta n_{old} + \delta n, \quad \delta n = (\text{range of } \Delta n)/1000 \quad (6)$$

Thus the parameters {x,Δn} give the solution of [12],

$$D_m + D_{wg} - D_{ts} = 0.0 \quad (7)$$

Finally, we select the following intermediate variables:

$$x_a = (x_i + x_c + x_f)/3.0 \quad (8)$$

$$\Delta n_a = (\Delta n_i + \Delta n_c + \Delta n_f)/3.0 \quad (9)$$

B. Two Designed Transmission Techniques

The modes of pulse propagation with amplification improve the performance of the optical communication system, namely: Soliton pulse propagation and MTDM pulse propagation.

Case I: In the case of a nonlinear dispersive medium, solitary waves (unchanged propagating shape) result from the balance between nonlinearity and dispersion. The nonlinear pulse propagation occurs in single mode fibers, then the initial peak power is given by [13]:

$$P_{peak} = 3.09\frac{\lambda_s^3 A_{eff.,s} D_t}{4\pi^2 c n_2 \tau^2} \quad (10)$$

where, c is the velocity of light in vacuum, n_2 is the Kerr coefficient, τ is the initial pulse broadening (T_{min}=10 τ, T_{min} is the minimum separation between pulses) ,and D_t is the total dispersion coefficient.

Case II: The MTDM bit rate B_{rm} for the first and second order dispersions is given [14-15]:

$$B_{rm}(\lambda, L_f, \Delta t) = \frac{1}{4\sigma(\lambda, L_f, \Delta t)} \quad (11)$$

where,

$$\sigma(\lambda, L_f, \Delta t) = \left[\frac{(\Delta t)^2}{8\ell n2}\left\{1 + A_1(\lambda, L_f)(\Delta t)^{-4} + A_2(\lambda, L_f)(\Delta t)^{-6}\right\}\right]^{0.5} \quad (12)$$

is the pulse width variation after a propagation distance L_f , Δt is the pulse width and L_f is the fiber length. For minimum value of σ we get maximum TDM bit rate is obtained when:

$$(\Delta t)^6 - A_1(\Delta t)^2 - 2A_2 = 0.0 \qquad (13)$$

A_1 and A_2 are given [14] as:

$$A_1(\lambda, L_f) = 15.365(\beta_2''(\lambda)L_f)^2 \qquad (14)$$

$$A_2(\lambda, L_f) = 10.65(\beta_3''(\lambda)L_f)^2 \qquad (15)$$

where,

$$\beta_2'' = \frac{\lambda}{2\pi C^2}\left(\lambda^2 \frac{\partial^2 n}{\partial \lambda^2}\right), \quad \sec^2 / m \qquad (16)$$

and

$$\beta_3'' = \frac{-\lambda^2}{2\pi C^3}\frac{\partial}{\partial \lambda}\left(\lambda^3 \frac{\partial^2 n}{\partial \lambda^2}\right), \quad \sec^3 / m \qquad (17)$$

3. Results and Discussion

At the values of temperatures 290° k, 300°k and $D_{ts} = -0.2, 0.0, 0.2$ psec/(km.nm) , the changes in N_L versus The changes in both central of Δn (Δnc) and central of x (xc) are shown in figures 1-12.

These figures shown that, the sub-optical window λ_c increase when the order of link is increased. The parallel calculating of both {x, Δn} yields values in positive linear interconnection with λ_c Where the results at D_{ts}=0.2 psec/km.nm have a little vary with the results at D_{ts}= –0.2 psec/km.nm where D_{ts}=0, at negative D_{ts}= Positive D_{ts}.

The comparisons between temperature at T=290 °k and at T=300 °k have been shown in Figs. 13-16. This comparison show that's, the spectral losses have been reduced when the T is reduced and it also transfers the zero dispersion wavelength to higher optical fiber frequencies.

Finally, whatever the type of transmission (with or without dispersion cancellation) there are negative correlations for the different bit-rates and the ambient temperature as shown in Figs.17-20.This phenomenon is due to the increase of both the spectral losses and the dispersion.

4. Conclusion

In this paper, a group of parameters {x_c, Δn_c} have been designed for (UW-SDM) and (UW-DWDM) to manage the chromatic dispersion, D_{ts} of single-mode binary glass fiber-optic cables for any group of variables {T, Dts}. A new mathematical model is utilized to calculate the parameters {x_c,Δn_c} through real technological boundaries $0.0 \le x_c \le 0.2$ and $0.001 \le \Delta n_c \le 0.01$, in parallel shape to obtain the given compressed dispersion. Linear correlations in general are found to integrate the general features of the present study. The present investigation is of deep impact on the design of fiber-optic cables in high-velocity optical fiber communication systems.

Based on the analysis of part (B) and the obtained results, the following conclusions are made:

a) Employing the transmission technique with dispersion cancellation, the soliton propagation improves the transmitted bit-rate by approximately 150 % w.r.t maximum time division multiplexing (MTDM).
b) Employing the transmission technique without dispersion cancellation, the soliton propagation yields better bit rate by approximately 100%.

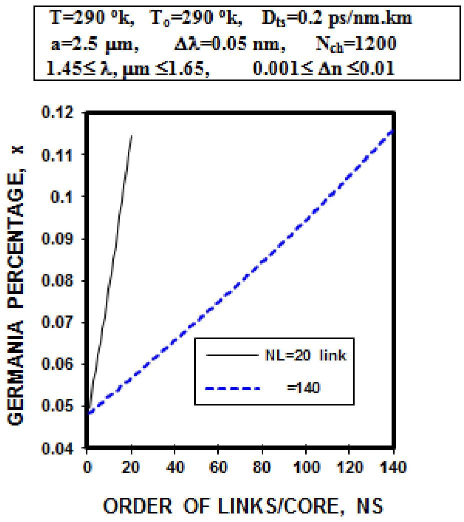

Fig.1.Variations of x_L against variations of N_S at the assumed set of parameters.

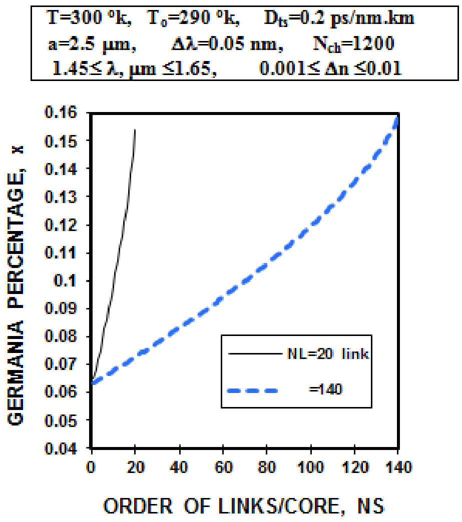

Fig. 2. Variations of x against variations of N_S at the assumed set of parameters

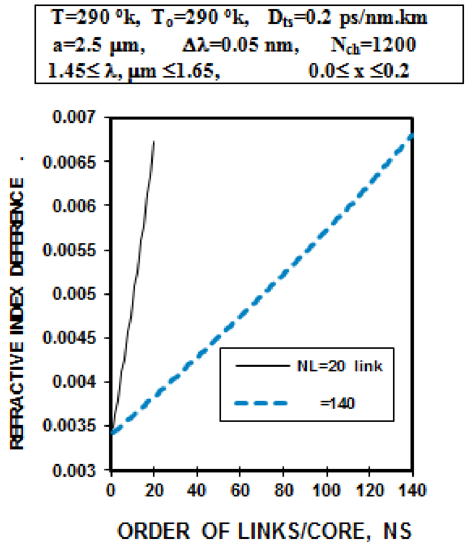

Fig. 3. Variations of refractive index difference,Δn against variations of N_S at the assumed set of parameters.

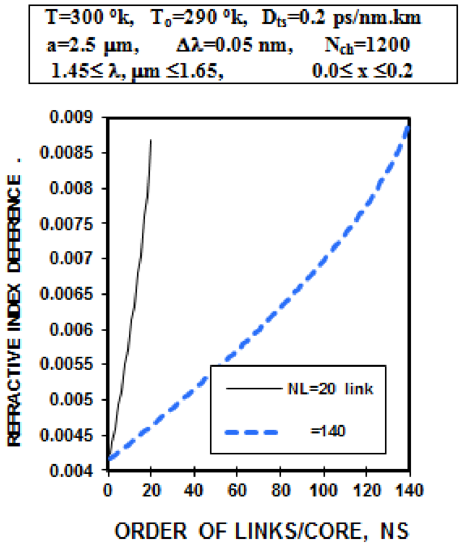

Fig. 4. Variations of refractive index difference Δn against variations of N_S at the assumed set of parameters

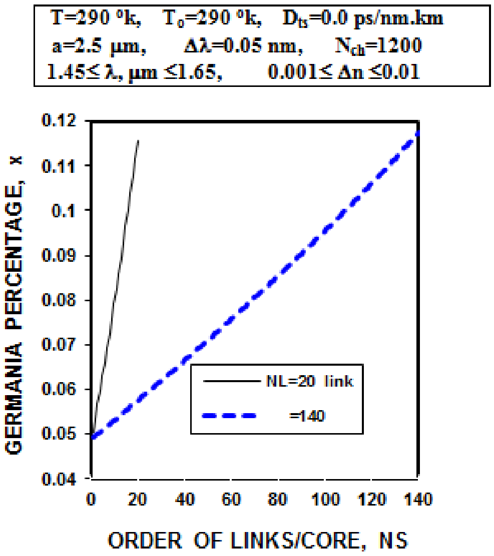

Fig. 5. Variations of x against variations of N_S at the assumed set of parameters.

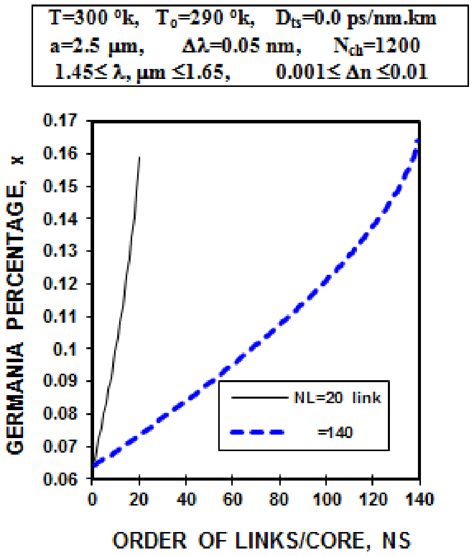

Fig. 6. Variations of x against variations of N_S at the assumed set of parameters

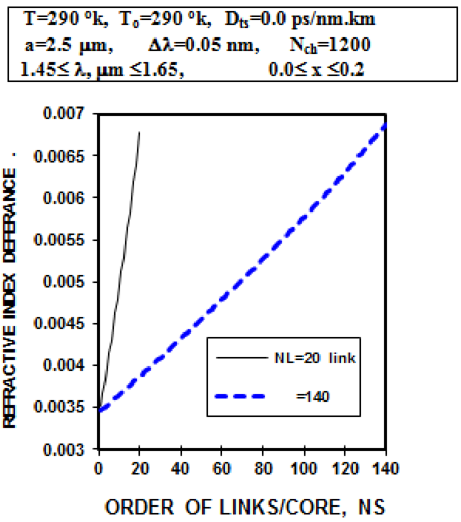

Fig. 7. Variations of refractive index difference, Δn against variations of N_S at the assumed set of parameters.

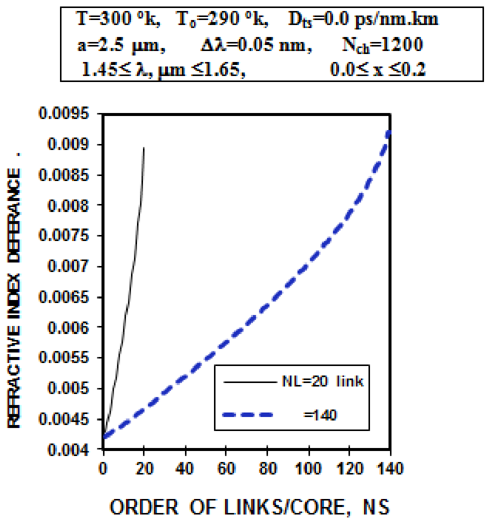

Fig. 8. Variations of refractive index difference,Δn against variations of N_S at the assumed set of parameters

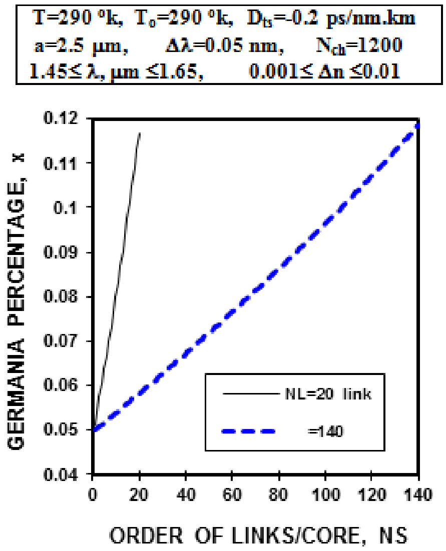

Fig. 9. Variations of x against variations of N_S at the assumed set of parameters.

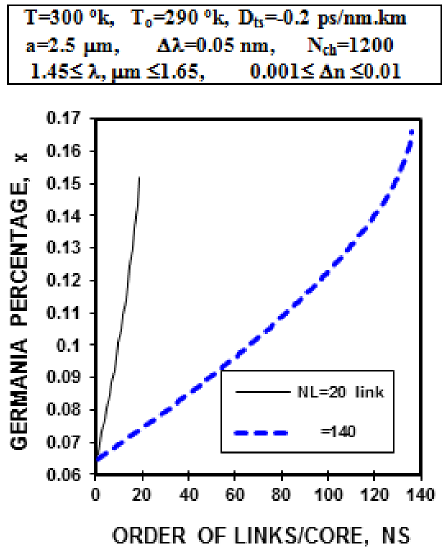

Fig. 10. Variations of x against variations of N_S at the assumed set of parameters

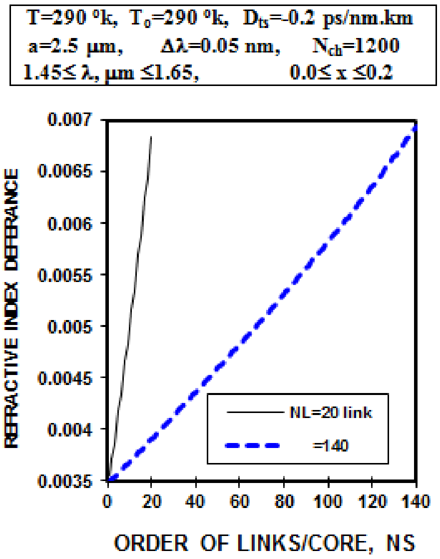

Fig.11. Variations of refractive index difference,Δn against variations of N_S at the assumed set of parameters.

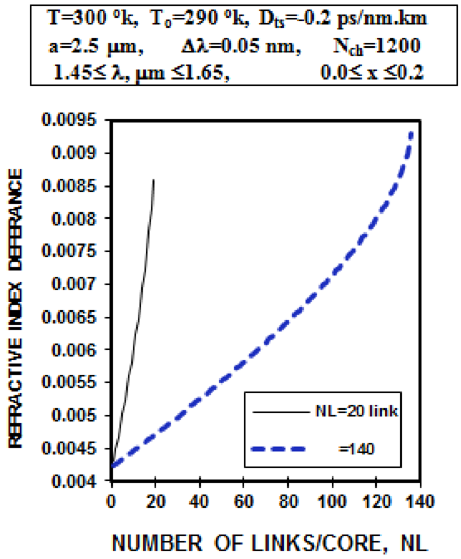

Fig. 12. Variations of refractive index difference,Δn against variations of N_S at the assumed set of parameters

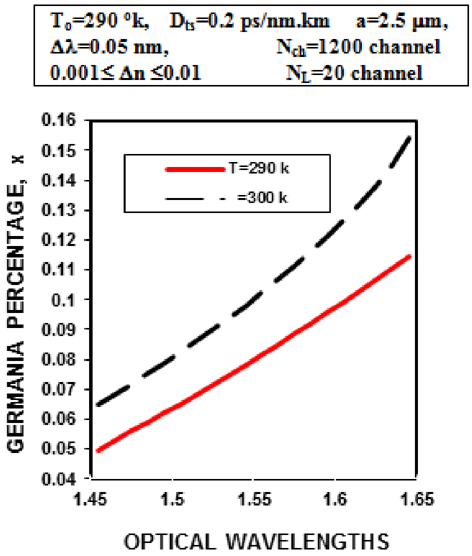

Fig.13. Variations of x against variations of optical wavelength,λ at the assumed set of parameters.

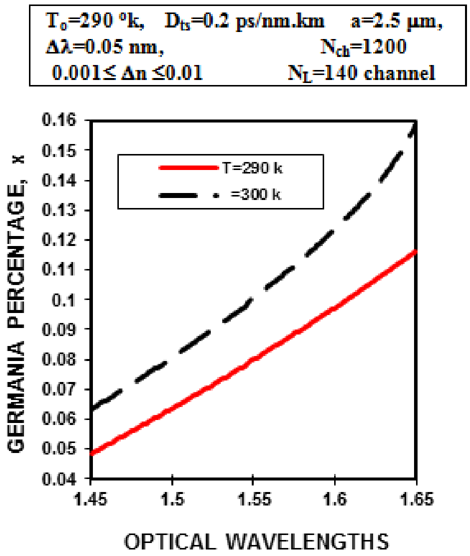

Fig. 14. Variations of x against variations of optical wavelength,λ at the assumed set of parameters

T_o=290 °k, D_{ts}=0.2 ps/nm.km a=2.5 μm, Δλ=0.05 nm, N_{ch}=1200, 0.0≤ x ≤0.2, N_L=20 channel

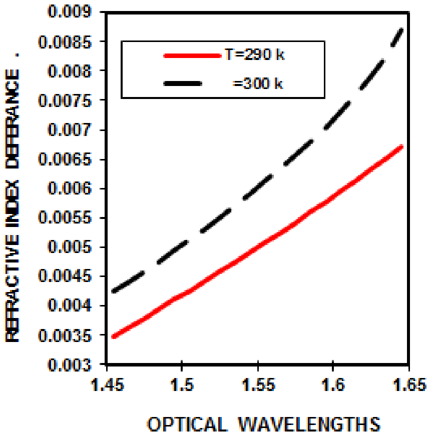

Fig.15. Variations of refractive index deference,Δn against variations of optical wavelength,λ at the assumed set of parameters.

T_o=290 °k, D_{ts}=0.2 ps/nm.km a=2.5 μm, Δλ=0.05 nm, N_{ch}=1200, 0.0≤ x ≤0.2, N_L=140 channel

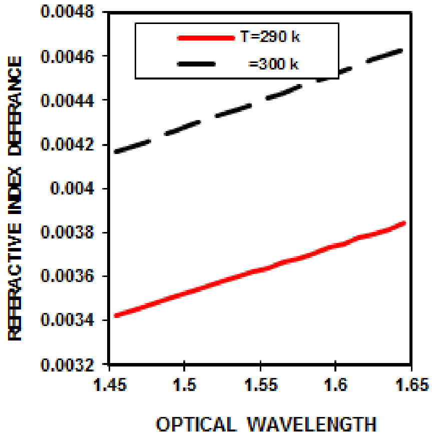

Fig. 16. Variations of refractive index deference,Δn against variations of optical wavelength,λ at the assumed set of parameters

L_f=100 km $λ_s$=1.55 μm

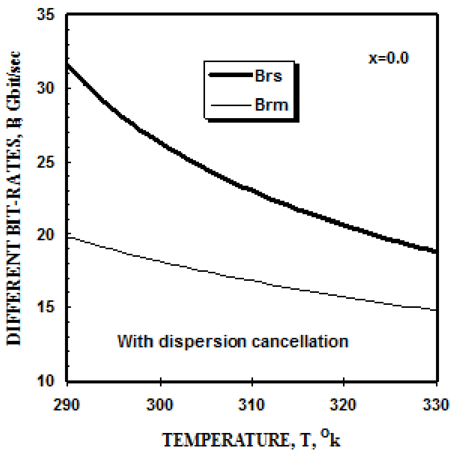

Fig. 17. Variations of B_r against variations of T at the assumed set of parameters.

L_f=100 km $λ_s$=1.55 μm

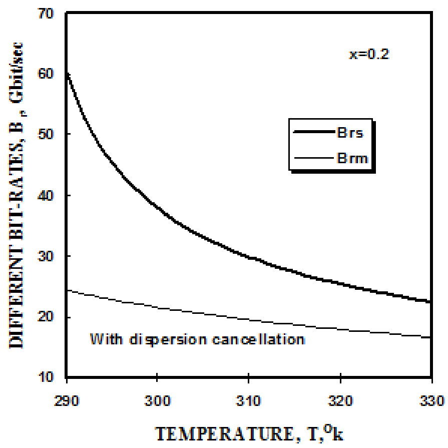

Fig. 18. Variations of B_r against variations of T at the assumed set of parameters.

L_f=100 km $λ_s$=1.55 μm

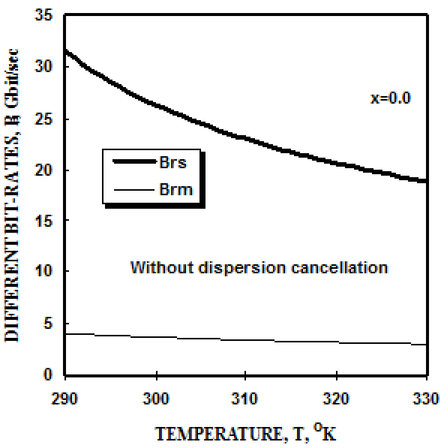

Fig. 19. Variations of B_r against variations of T at the assumed set of parameters.

L_f=100 km $λ_s$=1.55 μm

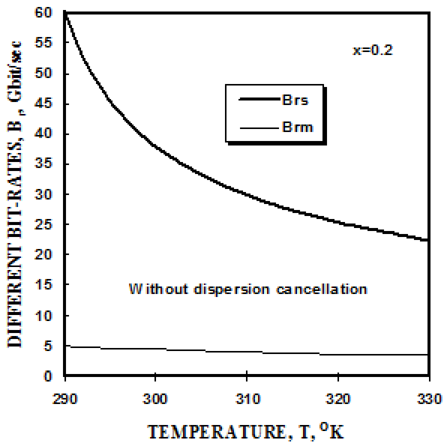

Fig. 20. Variations of B_r against variations of T at the assumed set of parameters

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