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Comparison of bit rate between single-mode and multimode optical fiber in case of step index and graded index at varied distances

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Abstract: Development of the telecommunication through optical fiber has been widely used. Optical fiber has the characteristics of long haul communication and large information carrying capacity. Optical fibers provide super transmission bandwidth. Optical fiber is currently a transmission medium of choice for long range distance and high speed transmission in telecommunications networks. The performance of any communication system is ultimately limited by available bandwidth of channel. Bandwidth of a channel depends upon maximum data rate that it can provide for transmission of data signal. This research paper focus on maximum bit rate in single mode fiber and multimode fiber in case of step index and graded index of fiber optic communication systems.

Keywords- Optical fiber, single mode, multimode, step index, graded index, maximum bit rate

I. INTRODUCTION:

Now days, fibers optic networks are gaining its popularity because it has high data rate speed, high density and high bandwidth for signal transmission etc. Compared with traditional copper cables, optical fibers cables can support much advance distance although exact distance is limited by many factors. For super fast optical communication, signal transmission distance has already become most vital issue. Optical fibers in different modes such as in single- mode step index, multimode step index and multimode graded mode provide enormous & unsurpassed transmission bandwidth with negligible latency & are now transmission medium of choice for long distance & high data rate transmission in telecommunication networks.

The optical signal might become weak over long distance that's only due to dispersion occur in the signal flow. There is a tradeoff present between bit rate of data signal and transmission distance. Thus we employ a method that has been adopted to analyze bit rate with respect to the optical transmission distance. This article will emphasize factors on the optical transmission distance and bit rate. Typically dispersion in fibers optic cables can have great impact on transmission distance and bit rate.

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II. Calculation of maximum bit rate:

(a) Maximum bit rate in step index optical fiber is given by

Maximum bit rate =0.2/ ($\Delta n_1 L/2\sqrt{3}c$) bit per sec.

Where

Δ is relative refractive index difference of fiber; n_1 is refractive index of core,

L is optical fiber length, c=2.998*10^8 m/s is speed of light

(b) Maximum bit rate in graded index optical fiber is given by

Maximum bit rate= $0.2/((\Delta^2)n_1 L/20\sqrt{3}c)$ bit per sec.

Where

Δ is relative refractive index difference; n_1 is refractive index of cladding,

L is length of fiber, c=2.998*10^8 m/s is speed of light

III. Factors that affect bit rate:

When signal dispersion occurred due to pulse broadening, it is alone limits the maximum possible bandwidth attainable with a particular optical fiber to the point where individual symbols can no longer be distinguished. Estimate of maximum bit rate for an optical channel with dispersion may be obtained by considering the light pulse at the output to have Gaussian shape with an rms pulse width. Bit rate of data transmission is inversely proportional to rms pulse broadening. So, we can say that bit rate is affected by relative refractive index difference, core refractive index and length of the fiber. As the transmission distance of light signal increase so there will be drop in the data speed. There should be low value of relative refractive index for maximum bit rate. So, if there is no any effect of dispersion occurs in optical fiber then we can achieve high bandwidth of signal. Single mode fibers have small relative refractive index difference than multimode fiber.

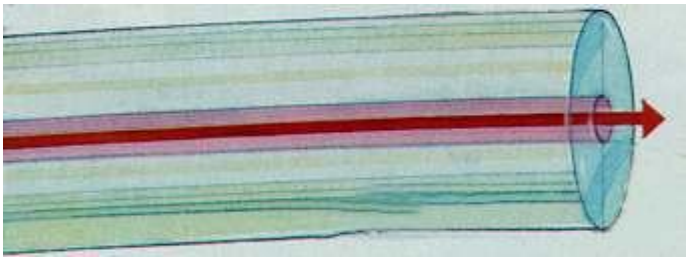

Figure 1 Light propagation in single-mode fiber

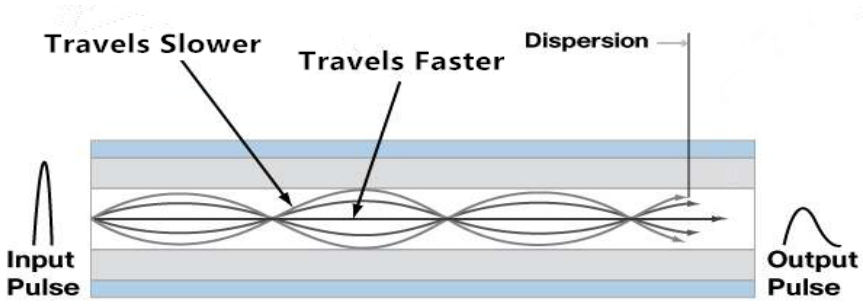

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Figure 2 Light propagation in multimode fiber

IV: Comparison of Maximum bit rate between single mode step index and single mode graded index optical fiber:

Maximum bit rate show the communications system performance excellent with minimum dispersion and minimum propagation loss. So it is always needs for a signal transmission system to attain maximum data rate. A fiber optics system should operate on those optical fibers which have a high bandwidth for signal propagation. A optical fiber is used as channel or transmission media in fiber optics communication system. Single mode fiber is used for high speed communication over long distances. To analyze maximum bit rate in single mode fiber, we have made a MATLAB program using SM1250G80 parameters for consideration in both cases of single mode step index and single mode graded index which provide relation of maximum bit rate with distances of optical path followed by a optical signal.

Table 1 Comparison of maximum bit rate in single mode step index & single mode graded index optical fiber

Distance (meter)	Maximum bit rate(Gbps) in single mode step index fiber	Maximum bit rate(Gbps) in single mode graded index fiber
100	0.5022	1762.4350
200	0.2511	881.2174
300	0.1674	587.4783
400	0.1255	440.6087
500	0.1004	352.4870
600	0.0837	293.7391
700	0.0717	251.7764
800	0.0627	220.3044
900	0.0558	195.8261
1000	0.0502	176.2435

From table 1, we conclude that single mode graded index fiber provide high bit rate of transmission that 176.2435Gbps for 1k.m range where a single mode step index fiber have maximum bit rate 0.0502Gbps or we can say 50.2Mbps for 1k.m range. Now, we plot this maximum bit rate with respect to varied distances by using MATLAB program. Single mode graded index fiber is used for particular purpose because it is so difficult to fabricate because of having graded index profile with in short core diameter. These fibers are ideally suited for high bandwidth and medium and long haul application using single mode injection laser sources. If we want to employ optical fiber such that at some distances in it level of signal strength remains same whole distance up to the target than optical amplifier is used in between fiber cable where the signal strength goes low. Graphical representation shows variation in the maximum bit rate at different varied distance.

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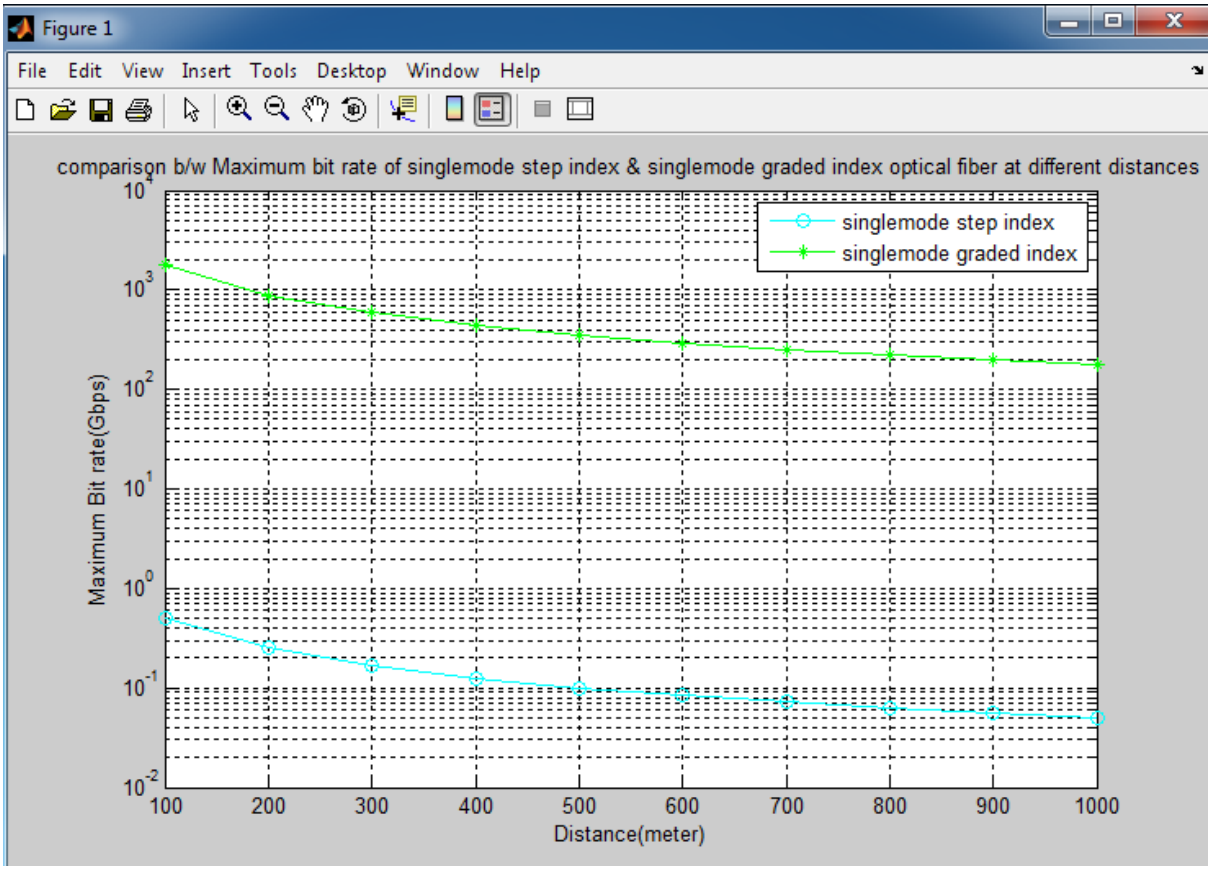

Figure 3 Maximum bit rate in single mode step index fiber and single mode graded index fiber at varied distances

V. Comparison of Maximum bit rate between multimode step index & multimode graded index optical fiber:

Bit rate is important characteristics parameter of a digital network. As for faster transmission of data, bit rate of signal should very high for fast access of data between two or more network. Optical fiber have a special character of high bit rate that goes GHz To THz. Every optical fibers have their own different character of producing loss. Bit rate depend on the speed of light, core refractive index & relative refractive difference. A intermodal dispersion effect does not produce usually in single mode fiber. It arises in multimode fiber when light signal disperse in fiber with different mode. That types of dispersion responsible for rms pulse broadening. For comparison we considered two multimode optical fibers represented as FG050LGA & GIF50C multimode fiber. Both have to consider core refractive index is 1.479 & numerical aperture of FG050LGA is 0.22 and GIF50C has 0.20 .These step index and graded index multimode fiber have relative refractive index 0.01 and 0.009 respectively. Maximum bit rate is calculated by using formula of find bit rate from rms pulse broadening. For that purpose we have made a MATLAB program that show maximum bit rate in different multimode fiber like step index and graded index with variation in propagation distance as a output table show.

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Table 2 Comparison of Maximum Bit rate in multimode step index & multimode graded index optical fiber

Distances (meter)	**Max. Bit rate (Gbps) in multimode step index (FG050LGA) fiber**	**Max. Bit rate (Gbps) in multimode graded index (GIF50C) fiber**
100	0.1404	173.3800
200	0.0702	86.6900
300	0.0468	57.7933
400	0.0351	43.3450
500	0.0280	34.6760
600	0.0234	28.8966
700	0.0200	24.7685
800	0.0175	21.6725
900	0.0156	19.2644
1000	0.0140	17.3380

As shown in the above table bit rate always greater in the graded index fiber from that of step index multimode fiber because intermodal dispersion effect in multimode graded index is compensated by refractive index parabolic profile that is radial decrease from center core to cladding surface. For graphical analysis of that fiber, we has made program in MATLAB that plot the two curve of multimode step index and graded index that show relationship of maximum bit rate to the varied distance.

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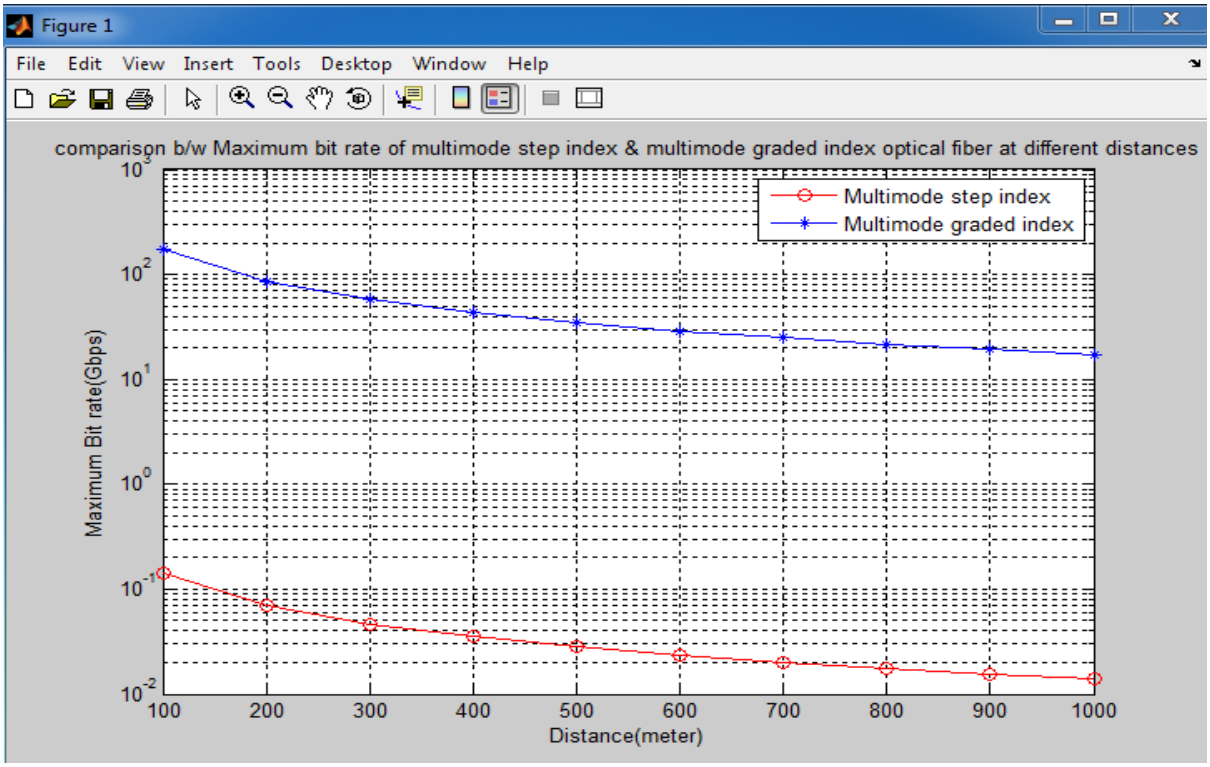

Figure 4 Maximum Bit rate in multimode step index & multimode graded index optical fiber at varied distances

At hundred meters distance maximum bit rate of graded index fiber is 173.38Gbps whereas the step index fiber has 140.4Mbps. As we transmission distance increase , bit rate in both multimode fiber reduce but step index fiber bit rate comparatively more less then graded index fiber.

VI. CONCLUSION:

It is important maximize the maximum data rate in optical fiber during fiber optics communication system. Maximum bit rate is inversely proportional to length of the fiber. In this paper we discussed variation of maximum bit rate in both single mode and multimode fiber in case of step index and graded index with respect to transmission distances. This paper concluded that maximum bit rate in single mode step index and single mode graded index is very large than multimode step index and multimode graded index optical fiber respectively. It is due to minimization of effect of pulse broadening in single mode optical fiber whereas pulse broadening is dominant in multimode optical fiber. So, single mode optical fiber provides a maximum bit rate advantage over multimode optical fiber.

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