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Performance Evaluation of Plastic and Glass Optical Fibers (POF and GOF) Using Optisystem

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Abstract-Plastic optical fibre (POF) is currently gaining popularity for short distance; being studied to investigate channel communication link performance and a possible replacement for glass optical fibre (GOF). The study present transmission system model simulation with software (Optisystem) to investigated optical communication link characteristics of POF and GOF under the same conditions. The model setup varied conditions as follows; 10m to 70km for data rates of 1Gb/s, 2Gb/s, 4Gb/s, 8Gb/s, and 10Gb/s. The study adopted measurement parameters like Q-factor, eye height, data rate and bit error rate (BER) as performance functions of the optical fibre characteristics with respect to length under different configurations. This study employed developed models to predict performance of POF and justify the trade-off in applications where a more expensive GOF can be substituted with POF as an alternative in order to establish operating limits that is based on performance and cost in distance consideration. The study proposed POF as a better medium for local area network (LAN) with its added advantages of installation simplicity, flexibility and low cost.

Keywords- *POF, GOF, Q-factor and Eye Height*

I. Introduction

Modern communications link are characterised with an explosion of information traffic such as internet, electronic commerce, computer networks, multimedia, voice, data, and video; has led to the need for a secure transmission medium with available bandwidth capabilities to withstand the traffic. Optical fibre is a medium for carrying information from one point to another in the form of light. Unlike copper, signal transmission in fibre optics is not electrical. Optical fibre, with its comparatively infinite bandwidth, satisfies this requirement and has proven promising solution. A basic fibre optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fibre cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal. The complexity of an optical system can range from very simple local area network to sophisticated and expensive long-distance such as telephone or cable television trunking network [1]. Fig. 1 presents a typical optical communication system.

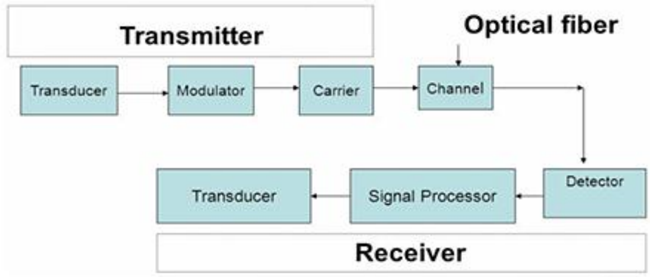

Figure 1. Optical Communication [2].

As a result of the ever-increasing demand for bandwidth, optical fibres have provided an excellent solution for high-speed transmission networks for both industrial and residential applications. Such applications as found in CCTV, automobile and telecommunication have enhanced high-speed connectivity especially for long-distance communication with very low latency[3]. Plastic optical fibre (POF) has a history that predates that of glass fibre, and yet it has been over shadowed by glass fibre in past decades due to the relatively high loss (typically 200-1000 dB/km) of early POF [4]. The global demand in communication firm is to develop system for cheap and reliable transmission media for short range communication with high data transmitting capacity. The study employed Optsystem software present to model and simulates communication link, different communication distance from 10m to 70km and data rates ranges 1Gb/s, 2Gb/s, 4Gb/s, 8Gb/s, and 10Gb/s. The work adopted performance evaluation indices such as eye diagram, bit error rate (BER) and data rate (dr).

II. Literature Review

A. Evolution in Optical Fibre Technology

Fibre-optic communication systems was first used in 1978 to transmit signals at 100 Mb/s of multimode architecture operating near 0.85μm as repeater spacing of less than 10 km but sufficiently larger than the heritage coaxial media system [5].The study went further and demonstrated transmission at 2

GB/s over 44 km of single-mode fibre. A decade after, the second generation light wave systems came into operation transmitting bit rates of up to 1.7 GB/s with a repeater spacing of 50 km for private purposes. Third generation (1990), light wave systems operating at 2.5 GB/s became available communication firm. According to [5], such systems are capable of operating at a bit rate of up to 10 GB/s with minimum loss in Optic Communication. The best performance was achieved using dispersion-shifted fibres in combination with lasers oscillating in a single longitudinal mode. The shortcomings of third-generation 1.55m systems is that the signal is regenerated periodically by using electronic repeaters spaced apart by 60–70 km. Fourth light wave generation systems came into existence (1996) with the aim to increase transmission distance and data rate to 11km and 5Gb/s respectively for commercial purpose and submarine cables. The use of optical amplificationfor repeater spacing and wavelength division multiplexing (WDM) to support bit rate was introduced. The fifth generation of fibre-optic communication systems is concerned with extending the wavelength range over WDM system for time function. The conventional wavelength window, known as the C band, covers the wavelength range 1.53–1.57µm [5]. This followed the introduction of single-mode fibre which propelled the system capacity to Gb/s with repeater spacing over 50km with an increase in the wavelength of system operation to 1.55µm with aim of lower medium loss and enhanced dispersion.

B. Classification of Optical Fibre And Its Characteristics

The optical fibre are categorised into two classes as follows;

1) Step Index (SI) Type

The step-index (SI) optical fibre has affinity to transmit light by reflecting at the boundary of the core and cladding. An impulse injected into the fibre is spread over a time interval that is equal to the difference of the arrival times of the slowest and fastest modes. The pulse travelled through certain distance by causing spreading to overlap (broadening dispersion) to such an extent that the signal could be scrambled. The step-index (SI) polymer optical fibre is aimed at low data rate transmission, image guide, and illumination. Fig. 2 presents a typical response of Step Index (SI) signal response.

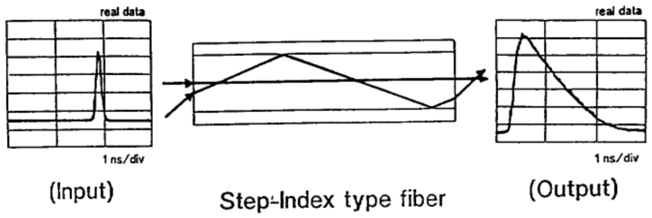

Figure 2. Step Index Optical Fibre Dispersion Response [3].

2) Graded Index (GI) Type

The Graded index optical fibres possess a refractive index (RI) distribution of parabolic form within the core. This act as a remedy to address pulse broadening issues occurrence in step-index optical fibre. The GI optical fibres exhibits less pulse broadening; could be expressed in the following way; it's utilized the shortest ray path of the fibre axis. The GI cable has greater speed compensation for long distance travelled. The signal oscillate ray path as shown in Fig. 3.

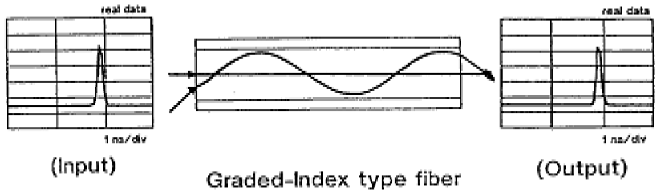

Figure 3. Graded Index Optical Fibre Dispersion Response [3].

C. Modes of Information Transfer in Optical Fibre

Step-Index Fibre: There are two main modes of transmitting information in optical fibres namely;

i. Single-mode step-index fibre allows for only one path, or mode, for light to travel within the fibre. It has high data rate with no modal dispersion but perform excellently in long distance. Fig. 4 illustrates it.

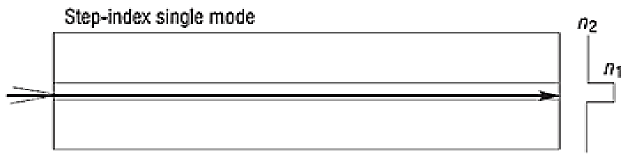

Figure 4. Step-Index single-mode

ii. Step-index multimodefibre has refractive index profile of variation from low to high and vice versa as measured from internal structure. The core is large in diameter with respect to numerical aperture characterized. The standard core/cladding diameter of a typical multimode fibre adopted used in telecommunication is 62.5/125 µm [6].Step index multimode fibre is deployed in applications communication that required high bandwidth of 1 GHz with distance of less than 3 km. This is applicable to local area network or a campus network backbone. Its major benefit includes low coupling losses and easy deployments; the shortcomings are bandwidth limitation, modal dispersion and low data rate. Fig. 5 revealed typical Step Index Multimode.

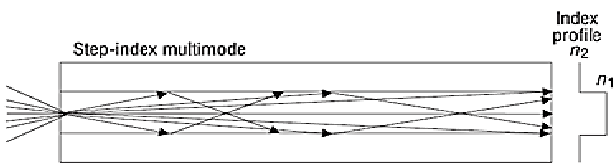

Figure 5. Step-Index Multimode

The study investigated mathematical expression of number of modes M_n *propagation* in a multimode step-index fibre; this is presented in Equation (1).

$$M_n = \frac{V^2}{2} \quad (1)$$

Where, Vis known as the normalized frequency, this relates to the fibre size to determine the refractive index, and the wavelength. According to [3] equation (2) can be deployed to established wavelength relationship with normalized frequency.

$$V = \frac{2\pi\rho}{\lambda}(n_{co}^2 - n_{cl}^2)^{\frac{1}{2}} \quad (2)$$

Where, $\boldsymbol{\lambda}$ wavelength of the propagated signal $\boldsymbol{\rho}$ is radius of core, n_{co} is refractive index of core, n_{cl} is the refractive index of the cladding.

D. Graded-index (GI) fibres

Graded (GI) compromise between larger core diameter and numerical aperture (NA) of multimode fibre. Although, GI exhibit higher bandwidth of the single-mode fibre. The creation of core with refraction index variation decreases parabolic like from centre core toward the cladding. The travelling light (signal) experiences higher index than light travelling in the higher modes. This revealed that the higher-order modes travel faster than the lower-order modes as stated, but modal dispersion decreases with increases in bandwidth of the fibre. Fig. 6 present characteristic pattern of GI fibre.

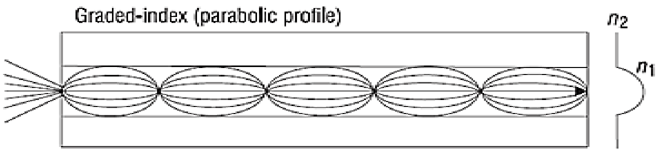

Figure 6. Graded index

E. Optical Signal Degradation

The design of optical fibre communications system is limited to loss, dispersion, and nonlinearity of the fibre. Although, fibre properties are dependant of wavelength, distance, dispersion and operating wavelength (operating window); these are factors of design. The attenuation effect reduces the signal power and the dispersion effect distorts the shape of the pulse and pose odds to the signal as discussed below.

1) Optical Signal Attenuation

Optical signal attenuation is vital indices design of an optical fibre communication link, as it factor of maximum transmission distance between a transmitter and receiver. Technically, the transmission link Optical loss is the sum of three major components: intrinsic loss, micro bending loss, and splicing loss. This can be determined through equation (3).

$$a_{dB}L = 10\log_{10}\frac{P_i}{P_o} \quad (3)$$

Where, α_{dB} present signal attenuation per unit length in decibels (Fibre loss); L is the fibre length; Pi is input (transmitted) optical power into the fibre and P_0 is the output (received) power from the fibre.

2) Dispersion

Dispersion is expressed as pulse spreading with an optical fibre. Light propagates through a fibre, elements such as numerical aperture (NA), core-diameter and refractive index profile. It can be expressed as symbol Δt, is defined as pulse spreading in an optical fibre revealed in equation (4); complimented by Fig. 7.

$$\Delta t = (\Delta t_{out} - \Delta t_{in}) \quad (4)$$

Figure 7. Dispersion; pulse broadening [6].

III. METHODOLOGY

The study designed an investigation analysis of signal distortion in Plastic Optics Fibre (POF) and Glass Optics Fibre (GOF) in Optisystem (Optiwaves) simulation environment. The design of optical fibre in the Optisystem environment adopted principle of single-mode fibre for glass optical fibre, while MMF for plastic optical fibre. The study employed input parameters for plastic optical fibre; and MMF fibre component based on the design specification and simulations as described in Table 1 [7].

TABLE I. SHOWING TRANSMISSION LINK PARAMETER SPECIFICATION.

parameter	Specification	
	GOF	POF
attenuation	0.2dB/km	16dB/km
Maximum sweep distance	70km	70km
Frequency (wavelength)	1550nm	1310nm

The work was setup as shown in Fig. 8 Optiwaves software; with variation data rate (Gb/s) using bit error rate (BER) and Q-factors as indices of performance evaluation.

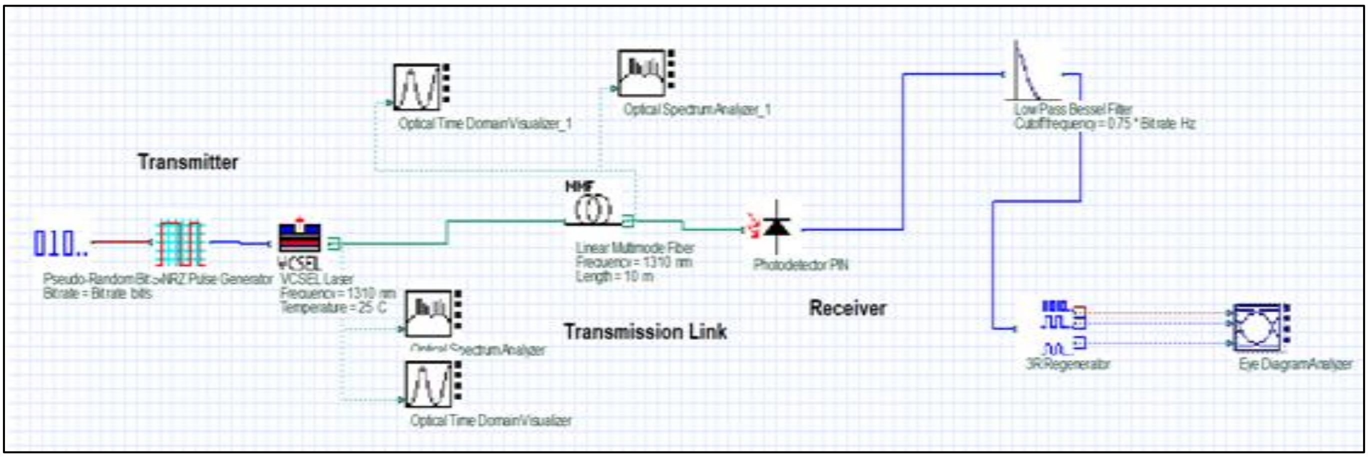

Figure 8. Design Simulation Architecture

The model simulation adapted network topology principle for glass and plastic as stated that; multimode fibre (MMF) POFs are popular for short distance applications and access networks due to lower costs. The MMF POFs was simulated and compared with simulations of MMF glass optical fibre as adapted by [8].

IV. Results and Discussion

The analysis performed on optical topologies described for POF and GOF using Optisystem, the Q-factor, Bit Error Rate, and Eye height were gotten for transmission distance which ranges from 10m to 70km for data rates of 1Gb/s, 2Gb/s, 4Gb/s, 8Gb/s, and 10Gb/s. It was observed that, the data rate of 1GB/s and 2GB/s has poor performance in eye height with 10m distance. The study considered 4Gb/s data rate for distance of POF and GOF respectively as shown in Fig. 9 and Fig. 10. POF gives better performance than GOF in eye height BER analyzer. Obviously, POF appear to be good medium for transmission of data up to 4Gb/s at 10meter distance.

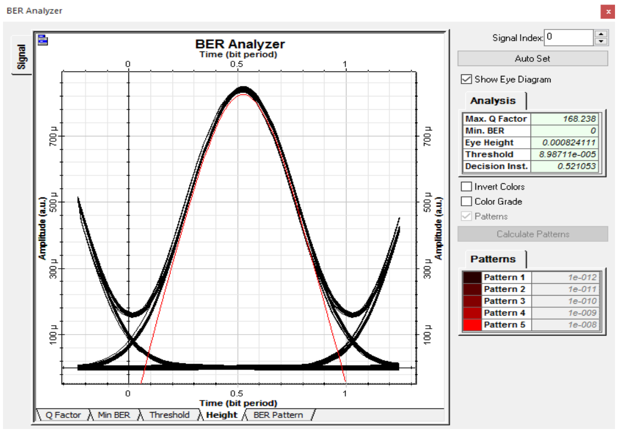

Figure 10. GOF Eye diagram at 10m

In further consideration of distance-medium performance, the study considered 30meters of both POF and GOF as shown in Fig. 11 and Fig. 12.

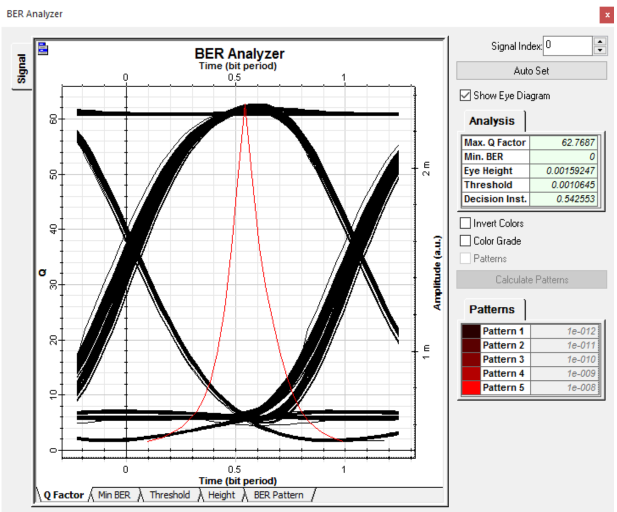

Figure 9. POF Eye diagram at 10m

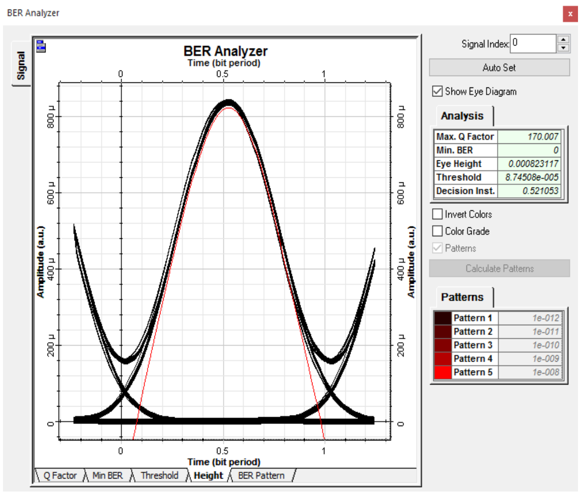

Figure 11. GOF Eye Height at 30m

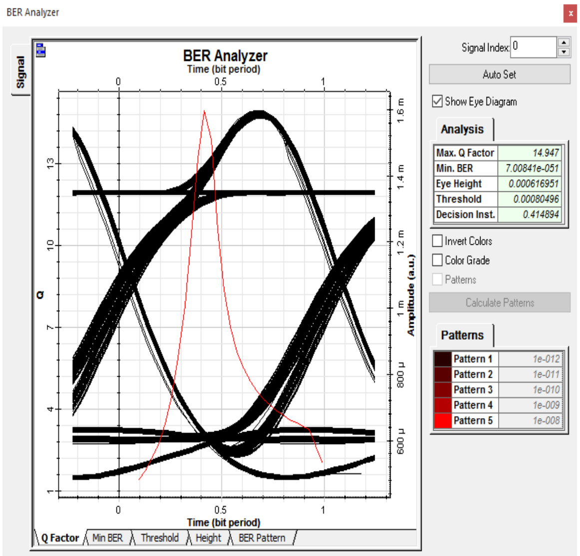

Figure 12. POF Eye Height 30m

BER analyzer shows roughly linearly increasing propensity with data rate due to increase in distance. This is supported by transmission performance degradation with increasing data rate is due to modal dispersion; fibre variance in behaviour with length can be explained transmission characteristics and installation error. The study considered cost of medium per meter distance to established more analysis on both media. The work employed quality factor (Q-Factor) to support POF analysis as shown in Fig. 13.

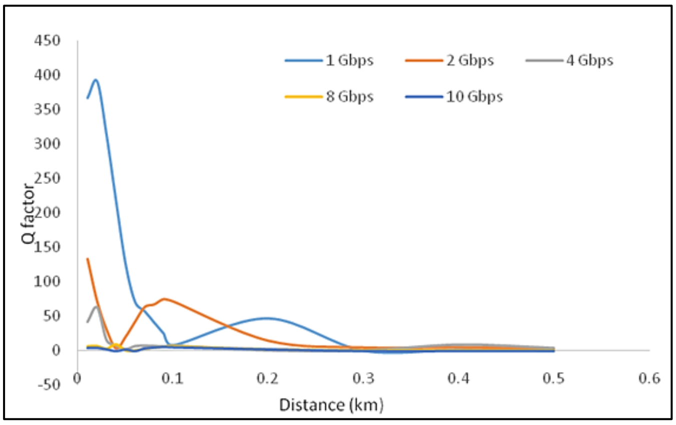

Figure 13. POFPerformance Q-factor and Distance (Gb/s)

The study shows that POF is suitable for distance up to 50m for 1 Gb/s transmission from Optisystem results with good Q factor; this is supported by literature. Although, nature of data and nodes are good factors to be considered in media selection; POF appears to be a suitable medium for short distance. Relatively, GOF is an expensive medium than POF, the work did not undermine glass performance as revealed in Fig. 14 showing the Q factor of POF and GOF with distance at different data rates.

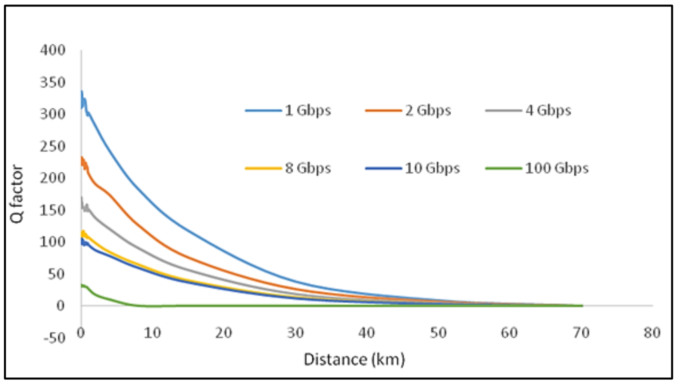

Figure 14. GOFPerformance Q-factor and Distance (Gb/s)

The study considered long distance for GOF due to its performance characteristic. The work shows that the Q-factor varies inversely with the data rate (b/s) and the length of fibre for both POF and GOF. However, while GOF performs better generally than POF in long distance; while POF perform relatively in short distance with added advantage of installation simplicity, flexibility and low cost.

V. CONCLUSION

The study investigated performance of POF and GOF media respectively; as POF gaining popularity over conventional glass. The study adopted indices of evaluation in a mimic communication link Optisystem environment to established performance of both media. The work varies distance (meter) and data rate (Gb/s) to investigate both media; there are complexities to analysis 1Gb/s and 2Gb/s due to poor performance but other data rate were studied as POF appear suitable for short distance, such as home applications (LAN) with good Q-factor and low cost. GOF is a promising medium for long-haul data transmission and better reception with minimum odds; this could be a good medium for cities applications but not for cost friendly. Therefore, the study revealed that both media has different interest and application purposes.

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