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SIMULATED MODELLING OF OPTICAL TRANSMISSION NETWORK FOR IMPROVED TRANSPORT OF ELECTRONIC HEALTH RECORDS

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Abstract

This work presents the simulated modeling of optical transmission network for improved transport of electronic health records. The aim is to improve interoperability of health data between hospitals at the speed of light and optimize quality of health care services. This was achieved using materials such as optic fiber, photo converters, filters, amplifiers, regenerators, isolators, and optisystem software. The result when simulated showed that data were able to be transmission between 54KM at the speed of 186,282 miles/secs which is very good.

Keywords: EHR, Optic Fiber, Photo Converters, Filters, Amplifiers, Regenerators

I. INTRODUCTION

Electronic health record (EHR) is a digital version of a patient medical history, containing all the clinical data relevant to that person's care under a particular provider. This clinical data include medications, laboratory test results, past medical statements, immunizations, radiology reports, among others to mention a few. This EHR is capable of being shared across different healthcare settings, by being embedded in network connected enterprise-wide information systems. The interoperability of this medical information system between healthcare providers will have huge potential to improve the efficiency, patient satisfaction and quality of health care service at a very fast rate and minimized economic cost, if the robust communication infrastructure is employed to boost its transmission [1; 2], but unfortunately factors like latency, signal interference, distortions, signal losses, poor signal strength and poor signal to noise ratio among others are obstacles which can hinder the realization of these benefits [3; 4]. The implications of this effect include corrupt signal, delay, high noise gain, poor signal strength, among other challenges like poor transmitter and receiver performances respectively. This paper proposed addressing this challenge through the modification of the conventional means of data transmission (copper) and improving the design of the transmission architectures channel using optic fiber. The choice of this tool is due to the huge benefits it offers especially speed and low implementation cost [5; 6].

All over the metropolis in most developing countries like Nigeria, optic fiber cables have been buried by various telecommunication companies for transmission purposes, however due to the huge bandwidth it has, most of the band are yet to be exploited and are reserved as dark fibers. The reserve fiber can be purchased and used for this transmission process, eliminating cost and delay time. However, despite the benefits offered by this transmission fiber, one of the major challenges is noise [7]. Noise can originate even from the transmitter, amplifier, receiver and other components used for the network design due to the basic electronics components used for their designs, thus inducing harmonics into the EHR signal [7; 8]. This as a result makes the quality of signal received corrupt, poor, unreliable, and incomplete, among other challenges. Hence, the work proposed the modeling of optical transmission system, utilizing filter to and amplifier to boast signal quality and mitigate noise, while transmitting the health record to the desired destination at the speed of light.

II. METHODOLOGY AND DESIGN

The methodology for the system development includes the engineering tools, graphical analysis, transmission routes, calculations and theory for non-linear pulse propagation based on Maxwell's equation [4], taking into consideration fiber dispersion [8, 9; 11], fiber losses, reflection, fiber non-linearity, bit error analysis, amplifier analysis [3, 10] using the gain spectrum model and laser rate model. The components descriptions are in table 1, detailing the major design components and their description types and specification as in table 1.

Table 1: Component description

Components	Description
NN (Tx/Rx -23 dBm sensitivity at 2.5 Gbps)	Subsystem of the transmitter and receiver
NRZ Pulse Generator	NRZ Pulse Generator
Pseudo-Random Bit Sequence Generator	Pseudo-Random Bit Sequence Generator
WDM Add and Drop	WDM Add and Drop
Power Amplifier	EDFA Ideal
Optical Fiber	Optical Fiber

Laser rate model for the data transmission

The laser rate model is developed considering the relationship between the variables of the carrier density (equation 1) and photo density (equation 2) using a deferential equation. This model is represented using the structure below [10];

$$\frac{dN}{dt} = \frac{I}{eV} - \frac{N}{Rn} - \sum_{i=1}^{i=M} RiGiPi \qquad \text{Equation 1}$$

$$\frac{dPi}{dt} = (TiGi - \frac{1}{rp}) Pi + \beta I \frac{N}{Rr}$$ Equation 2.

where N is the carrier density, P is the photon density, I is applied current, e is the elementary charge, V is volume of active region, Rn is the carrier lifetime, Gi is the gain coefficient, R is the confinement factor, rp is the photon lifetime, β is the spontaneous emission, Rr is the radioactive recombination time constant, M is the number of modes modeled, and i is the mode number.

III. OPTICAL MODEL OF THE TRANSMISSION NETWORK

The model of the network was achieved using optical fiber to connect the channel of transmission between two hospitals seprated by 54KM apart which is assumed to be distance between Enugu and Awka teaching hospitals respectively. The model in equation 1 and 2 were used to transmit the EHR to the destination after it has been converted to light by electrical to optic converter system and transmitted. The flow chart of the optical network used for the EHR transmission was presented in figure 1;

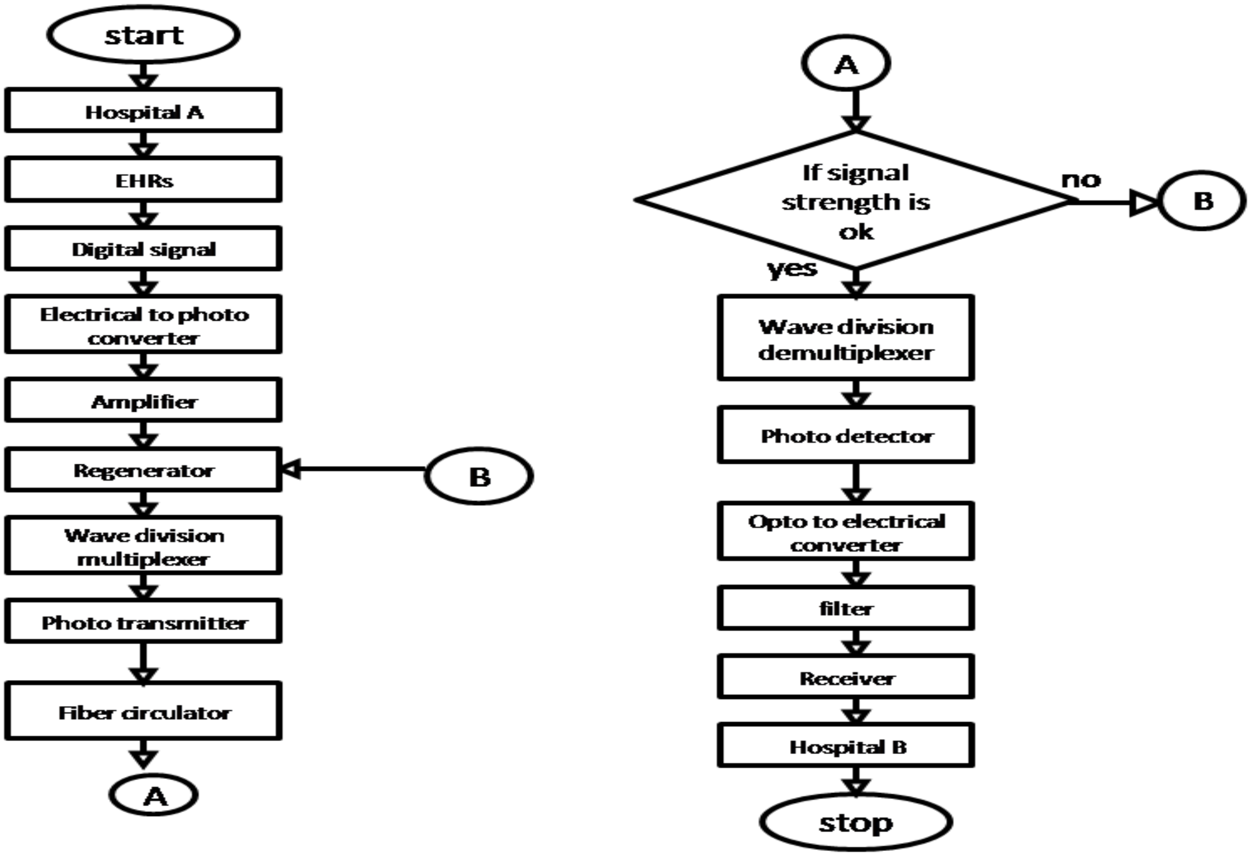

Figure 1: System flow chart

From the model in figure 1, the data of the patient health record which is in digital form is converted to light using and then amplified for transmission via the optical channel based on wave division multiplying. During the transmission the signal are regenerated and circulated to boast can compensate for loss while the filter was coupled to mitigate harmonics impact on the signal quality. At the destination point, the data are converted back to electrical signal and then decoded into the computer for interpretation. The simulation model of the network was presented in figure 2 using optical software.

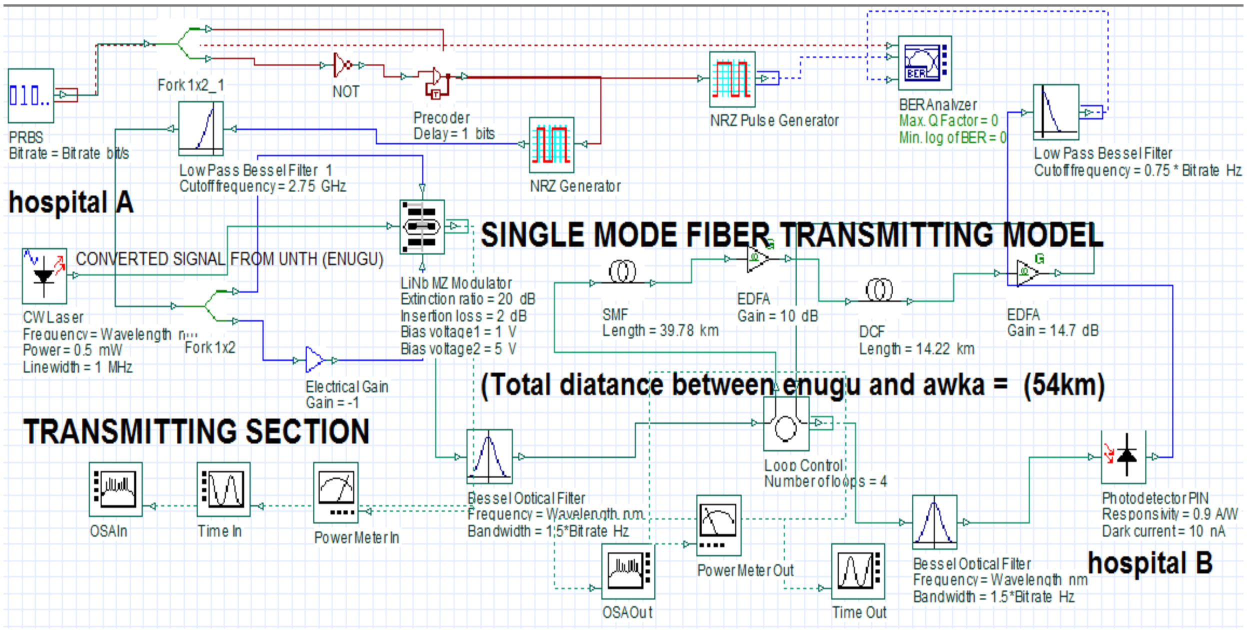

Figure 2: Optical transmission network

In the model of figure 2, the optical transmission network for electronic health record between the two hospitals has been developed using single model fiber which is recommended [4] for long range transmission. During the transmission process, the circulator regenerates the signal which is amplified and demultiplexed at a wavelength of 1550nm while the optical isolator is essentially the passive device which allows flow of the optical signal (for a particular wavelength or a wavelength band) in one band preventing reflections in the backward direction. This data is transmitted at about 25GB with better quality due to amplification and filtration to the receiver end (secondary hospital). The set up designed for receiving the transmitted data is presented in figure 3.

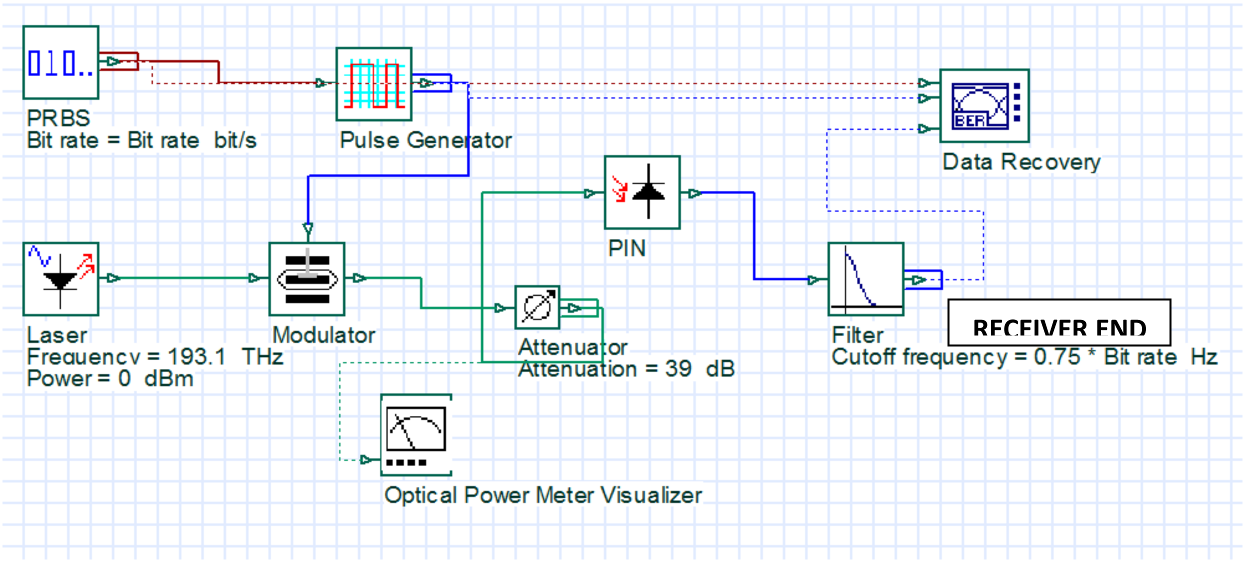

Figure 3: Implementation of the receiver setup at hospital B

From hospital B, the receiving system is setup to decode optical signal transmitted from hospital A. The receiver is designed using a photo detector and filter, the process is to ensure a noise free signal at the received end before conversion to electrical signal.

Table 2: simulation parameters

Parameters	**Values**
fiber model	SMF
Input power	100 dBm
Laser frequency	193.1Hz
Frequency of transmitter	1550nm
Transmission distance	54km
Attenuation of the cable section	0.2Db/km
Fiber core	8-10m/d
Cut off frequency	0.75 * bitrate Hz
Reserved dark fiber bandwidth	25GB

IV. RESULTS

The OSA analyzes the signal to noise ratio in the hospital B, 54km away from the transmitting hospital (A). The OSA is set at a frequency between 193.1 to 193.3Hz at a resolution bandwidth of 0.01nm to analyze the signal strength against wavelength and frequency respectively. The receiver signal received by the photo detector is presented in figure 4, with maximum amplitude recorded at 17.78dBm and the minimum amplitude is recorded at -105.609dBm.

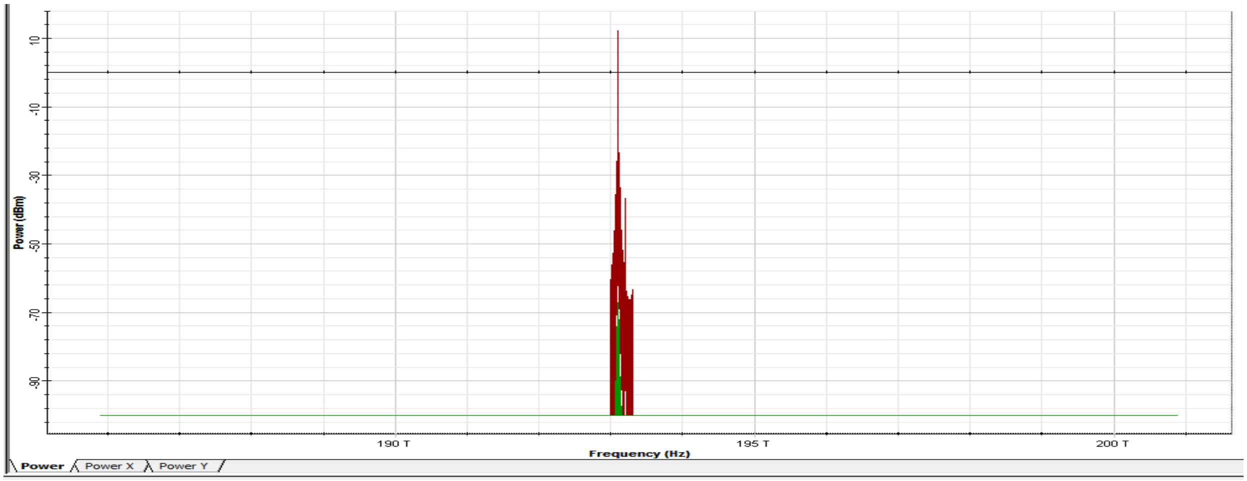

Figure 4: Receiver sampled signal result

From the result of the photo detector (receiver), it was observed that the signal is accompanied with certain degree of noise. To eliminate this effect, the filter incorporated in the receiver model in figure 3, is used to remove the noise at the cut off frequency specified in table 2. The eliminated noise is visualized using the OSA as shown in figure 5;

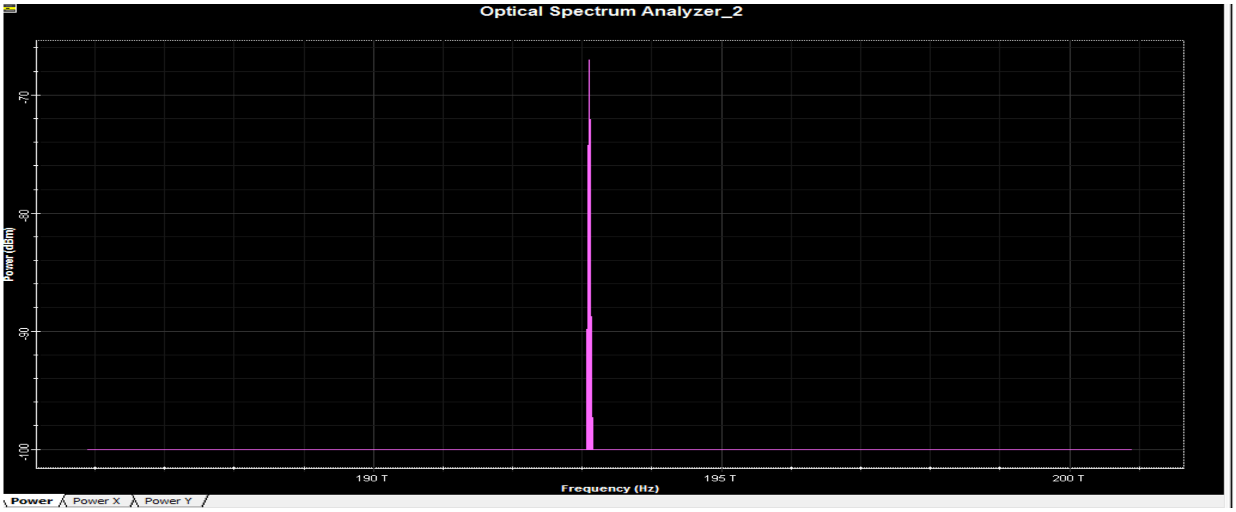

Figure 5: Hospital B receiver noise signal

From the result of the noise analysis, the noise signal simulated at a wavelength of 1552m and frequency of 193.4e + 012Hz was recorded with a gain of -38.1788dBm for the noise power. The result in figure 6 presents the performance of the filtered signal with gain of -100dBm as the signal quality with a power strength of 19.16dBm.

The implication of the negative gain achieved is due to the amplifier used to boast the signal based on the feedback propagation principal to ensure better signal stability, strength, gain and quality as show below; this result is summarized and recorded in table 3.

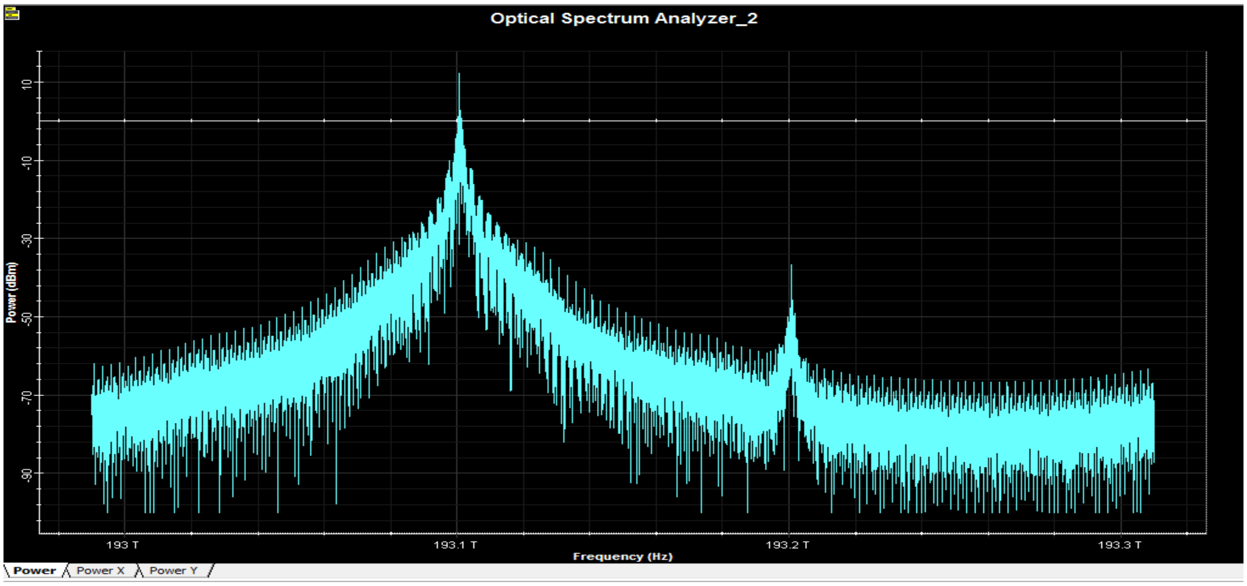

Figure 6: Filtered signal

Evaluating signal result with eye diagram

The result received will be analyzed using eye diagram. The eye diagram is an indicator of the quality of signals in high-speed digital transmission systems. Oscilloscope generates an eye diagram by overlaying sweeps of different segments of a long data stream driven by a master clock. The triggering edge may be positive or negative, but the displayed pulse that appears after a delay period may go either way; there is no way of knowing beforehand the value of an arbitrary bit. Therefore, when many such transitions have been overlaid, positive and negative pulses are superimposed on each other. This eye diagram presents the quality factor performance, minimum and maximum bit error rate, threshold and eye amplitude of the signal. The parameters are generated from the simulation result performed and the eye result is presented in figure 4, of which the signal attributes mentioned will be analyzed. The implication of this analysis is to evaluate the quality of signal received and the general performance of the optical transmission system using the received signal.

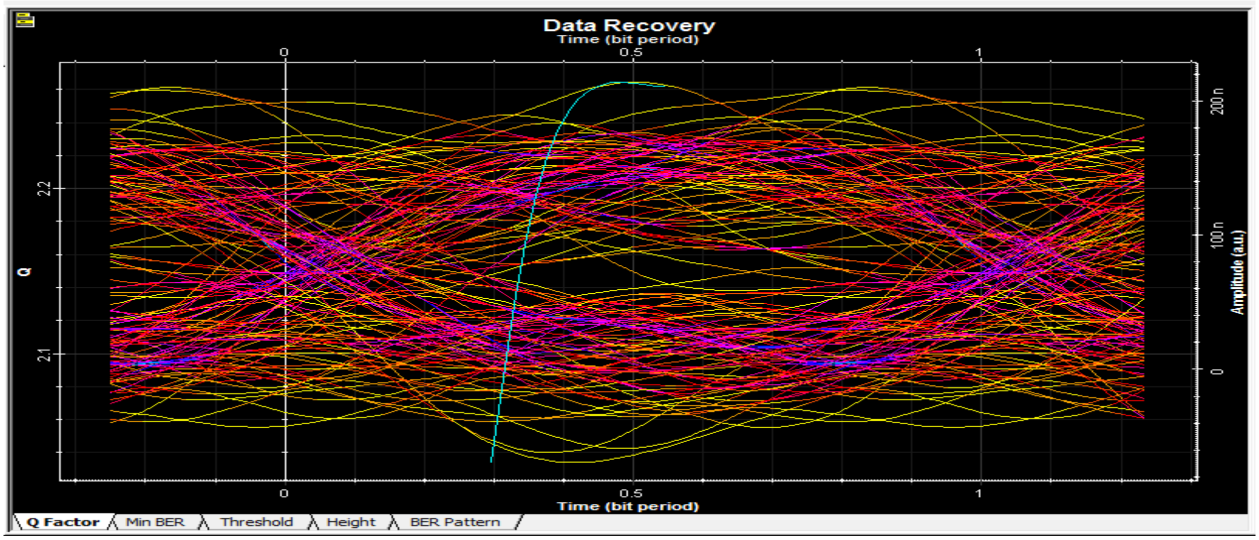

Figure 4: Eye diagram analysis of the received EHR signal with Quality factor

From the result presented, the quality factor of the signal is analyzed. The aim is to identify the signal to noise ratio required to obtain a Specific bit error rate for the optical signal, and the eye shows a maximum quality factor of 2.26 as shown in figure 5.

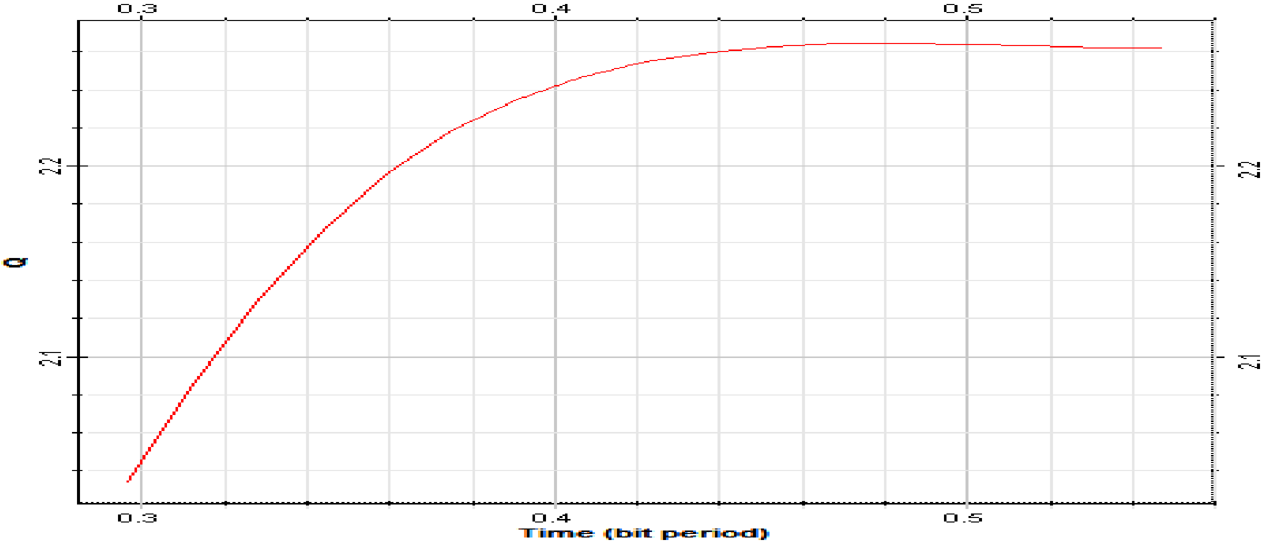

Figure 5: Maximum Quality factor

The signal minimum bit error rate is also identified in the eye diagram (figure 4) displaying the log of BER per given time of transmission. It was observed that the rays travel with a constant Q factor and a minimum bit error rate of (0.0118) considering the distance of the transmission which is 54 km. This result is presented using the graph in figure 6 with the minimum bit error rate displayed in the oscillator as;

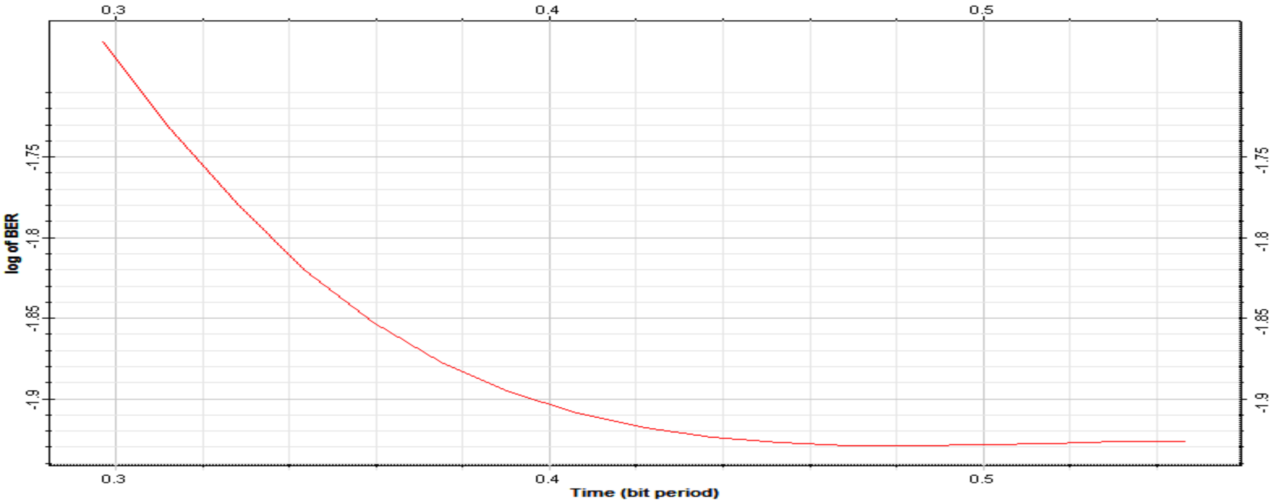

Figure 6: Minimum bit error value of the received data

The threshold value is determined by the amplitude of the signal per given period. From the eye diagram in figure 4, the threshold value is approximately 7.8e-008. The signal threshold is presented in figure 7.

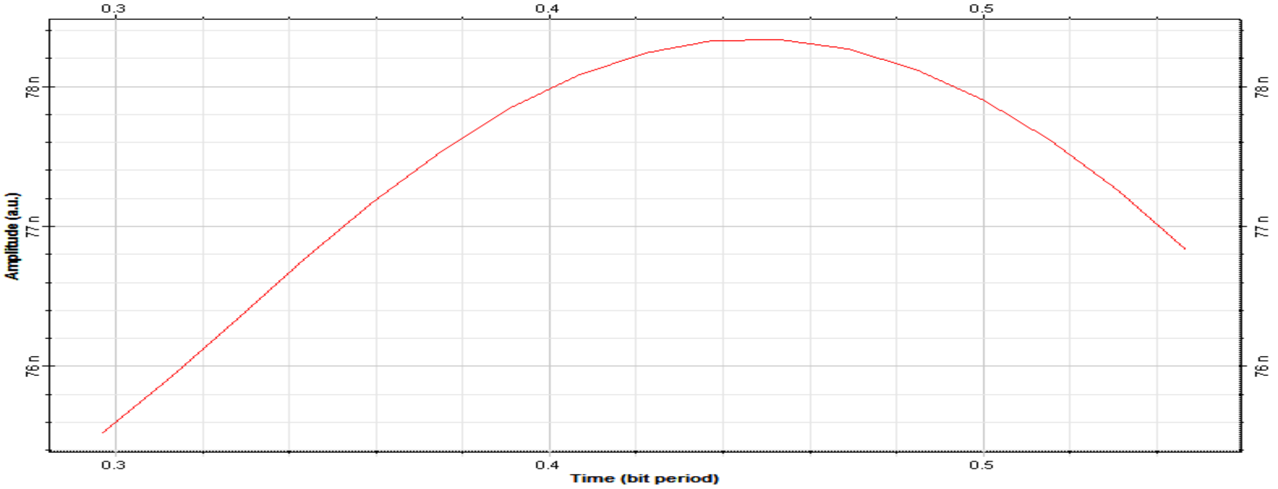

Figure 7: Threshold analysis of the recovered data at the receiver point

The eye amplitude or height refers to the distance from the base to the peak of the eye per given period. The allowed minimum height value of the eye diagram is inversely proportional to the photosensitive. High photosensitive could assess data at low height value of eye diagram whereas low photosensitive requires high eye diagram height value for data assessment. If there is any fixation on the photosensitive value, the increase in data transmission rate will give similar eye diagram height value. From the result of the eye in figure 4; the eye height (-1.6579e-008) of the data recovered is presented as figure 8;

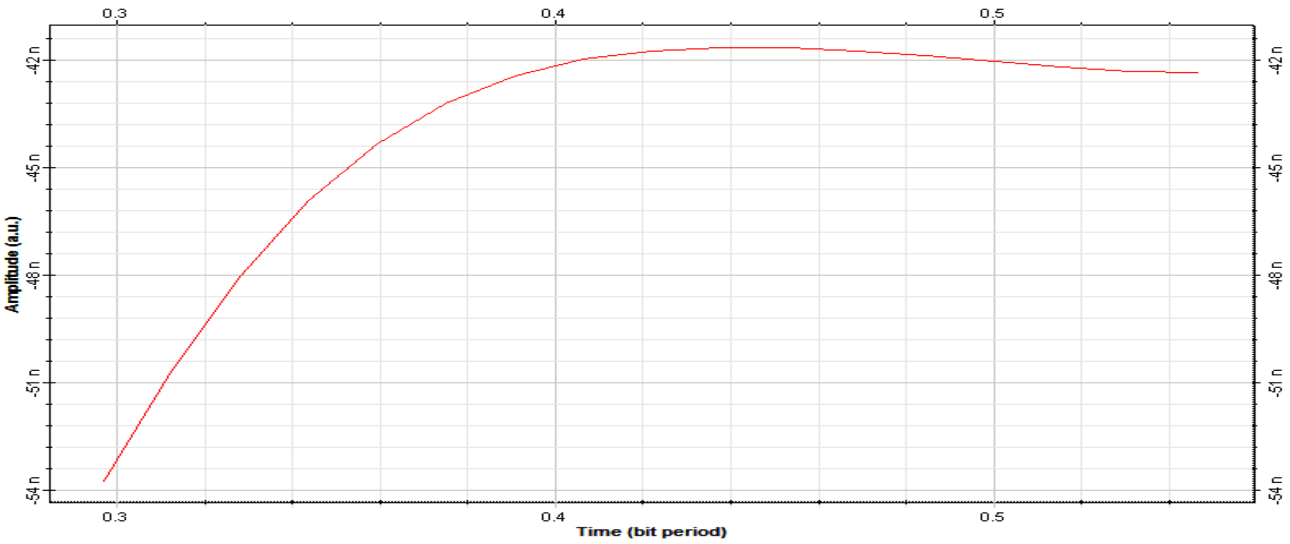

Figure 8: Eye height of data recovered

From the analysis performed so far using the eye diagram, it was observed that the quality factor was the same for the threshold value, bit error rate and eye height. The implication of this result shows that the signal obtained is of good gain and stability as summarized in the table 3.

Table 3: Summary of receiver performance at hospital B

Characteristics Parameters	**Results**
Total Power (dBm)	19.15718737111082
Total Power (W)	0.0823604549811031
Signal Power (dBm)	19.15717934692081
Signal Power (W)	0.0823603028089349
Sampled Signal Power (dBm)	19.15717934692081
Sampled Signal Power (W)	0.08236030280893494
Sampled Signal Power (Photons)	643.6909304471282e+015
Parameterized Signal Power (dBm)	-100
Parameterized Signal Power (W)	0
Noise Power (dBm)	-38.17664771390023
Noise Power (W)	0.1521721681915929e-006
Total Power X (dBm)	19.15718335901767
Total Power X (W)	0.08236037889501909
Signal Power X (dBm)	19.15717934692081
Signal Power X (W)	0.08236030280893499
Sampled Signal Power X (dBm)	19.15717934692081
Sampled Signal Power X (W)	0.08236030280893499
Sampled Signal Power X (Photons)	643.6909304471286e+015
Parameterized Signal Power X (dBm)	-100
Parameterized Signal Power X (W)	0

Signal Power Y (dBm)	-100
Signal Power Y (W)	0.3088016746017303e-033
Sampled Signal Power Y (dBm)	-100
Sampled Signal Power Y (W)	0.3088016746017303e-033
Sampled Signal Power Y (Photons)	2.413454424871966e-015
Parameterized Signal Power Y (dBm)	-100
Parameterized Signal Power Y (W)	0
Noise Power Y (dBm)	-41.18694767054004
Noise Power Y (W)	76.08608409579642e-009

V. CONCLUSION

In recent times, the need to achieve quality of service at the receiver end of a communication network is of ultimate importance for a completely satisfied communication process. This quality of data received is often affected by noise, latency, dispersion, losses among others depending on the transmission route. In the case of optic fiber transmission system noise is inevitable, especially for long distance transmission. This noise effects often make the quality of service not reliable at the receiver end. This work however, has successfully proposed and implemented an optical communication system for the transmission of electronic health record at the speed of light (186,282miles/sec) using single mode optic fiber. The work developed the transmission route using a photo transmitter, photo detector, feed-back amplifier and also a filter incorporated in the transducer sections. The result of the signal received was analyzed using oscillator and optical signal analyzer, indicating a high quality of signal decoded at the receiver end, based on the value of gain and signal strength recorded.

VI. AUTHOR CONTRIBUTION

All authors contributed in the development of this research and collectively agreed to the publication.

VII. AUTHORS DECLEARATION

The authors declare no conflicting interest in this paper.

VIII. FUNDING

None

IX. DATA AVAILABILITY

Not applicable here

X. REFERENCE

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