Design of Passive Optical Network For Hospital Management

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***Abstract*— The major characteristics of optical fiber are that data can be transmitted in the form of light with reduced dispersion and attenuation. The aim is to design a passive optical system in hospital environment with reduced noise figure, BER, increased gain and quality factor for effective transmission of data using OptiSystem software. Data considered in this scenario is image (X-ray) and video in the network design. A passive optical network (PON) was designed floor wise and ward wise and the parameters like optical signal to noise ratio (OSNR), gain, noise figure, output signal, BER (Bit Error Rate), Q factor (Quality factor) were checked after successful transmission of data which falls within the expected range. The expected value of quality factor should be greater than 6 and that of BER is 10^{-12} for worst case. Thus any value of BER less than the given value is accepted.**

Keywords* — *PON, BER, Q Factor, OSNR, UDBS.

I. Introduction

Nowadays optical fiber has secured a prominent place amongst the most advanced transmission medium. It is the one that is having the potential to extend support to the next generation utilities and services. A passive optical network (PON) is a network which by its nature provides a variety of broadband services to customer by enabling access through optical fiber. PON allows removing all active components between the server and client introducing in place optical passive components to guide the traffic throughout the network. The networks used in hospitals nowadays are choked by various internet based services and applications and consumes a huge amount of bandwidth [1], [2].

With the growth of the usage of video conferencing, integration of digital voice services in the LAN network, streaming video content and various other on-line applications the problem of bandwidth in hospitals are increasing day by day also its creating several significant security threats and issues in comparisons to the conventional copper based network. This dramatic increase in demand for bandwidth among user populations, many hospitals is finding the right data communications solution - The Passive Optical Network [3], [4].

II. PON Implementation in Hospital

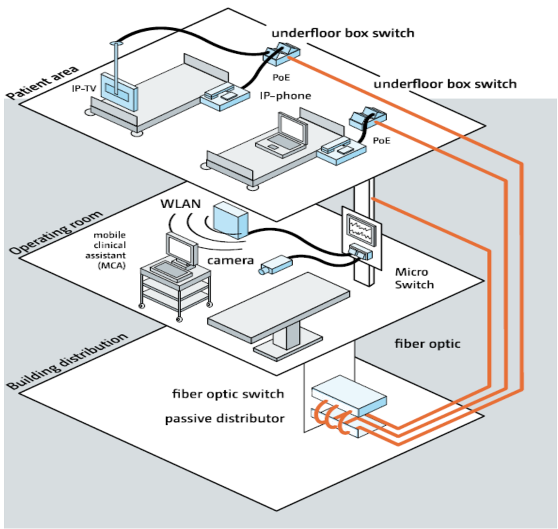

Fig. 1.a: Overview of Hospital model [5].

Figure 1.a shows the general representation for the floor wise modeling which gives an idea of how the optical network will be managed for the entire scenario (hospital).

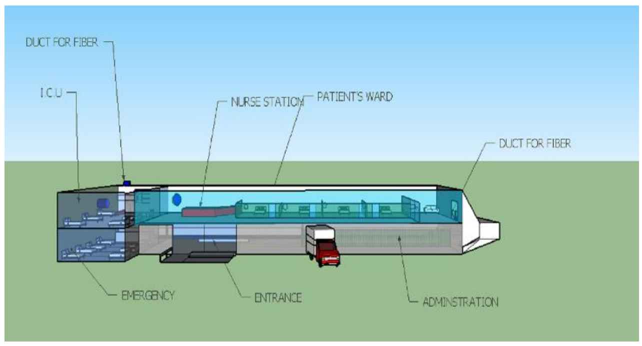

Fig. 1.b: Front view of hospital

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For design of passive optical network for hospital management data such as image (X-ray) was considered for transmission. Thus for transmission of this data in optical form, coding was done in C to get pixel value of the image. As for transmission in Optisystem, .dat file is required; the pixel value was converted to .dat and uploaded in the bit sequence generator. Thus this data was transmitted to destination (wards or hospital) using modulator carried by the optical fiber cable [6], [7].

The length of the optical fiber was varied from 100 m to 5km. The following parameters are kept constant as shown in table I.

TABLE 1

Parameters of simulations

Parameters	Value
CW Laser Power	10mW to 5W
Center Wavelength	1550nm
Center Frequency	193.414Thz
Extinction ratio of Mach-Zehnder modulator	30dB

The simulations are done using Optisystem which is a comprehensive software design suite that enables users to plan, test and simulate optical links in the transmission layer of modern optical networks [8].

A. UNI-DIRECTIONAL TRANSMISSION

In the simulation a basic communication system was considered with the help of User Defined Bit Sequence generator (UDBS) [7]. X-ray data was transmitted to check for BER, gain and quality factor as shown in figure 2.

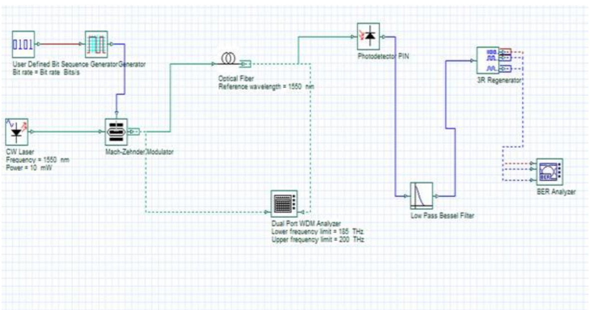

Fig. 2: Optical Communication system (using User Defined Bit Sequence generator)

Table II gives the details of the gain, noise figure, quality factor and BER by varying the length as shown.

TABLE II

Gain, Noise Figure, Quality Factor and BER of the Optical Communication System

Length [m]	Gain [dB]	Noise figure [dB]	Quality factor	BER
10	-1.978	1.978	15.421	1.38E-54
20	-3.971	3.971	14.24	5.91E-47
30	-6.011	6.011	13.018	1.17E-40
40	-6.581	6.581	13.018	1.17E-39
50	-7.121	7.121	12.956	1.45E-38

The eye pattern diagram for the optical system using user defined bit sequence is shown in figure 3.

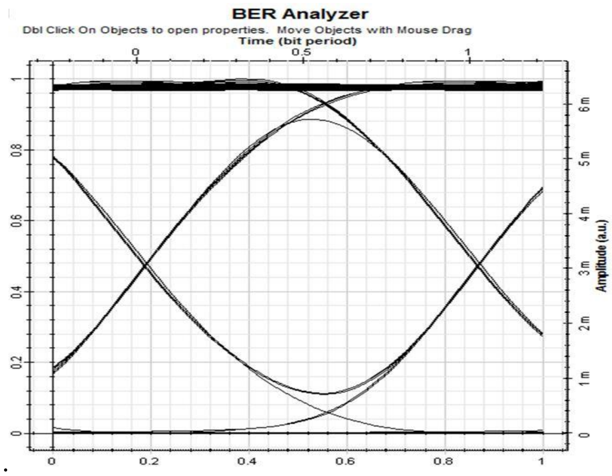

Fig. 3: Eye Pattern diagram for optical system using User Defined Bit Sequence.

B. BI-DIRECTIONAL COMMUNICATION

Bi-directional communication is the one in which communication takes place from hospital to wards and wards to the hospital [9]. For bi-directional transmission circulators were used both at the transmitter and receivers.

Optical delay generator was used as the same optical cable was used for transmission in both the direction it may cause interference which results in loss of data. The simulations for bi-directional condition were verified using spectrum analyzers and BER analyzers at both ends as shown in figure 4.

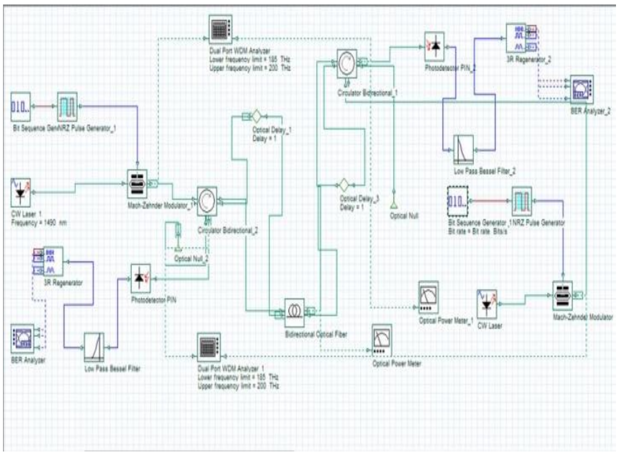

Fig. 4: Bi-directional Optical Communication System.

The communication distance was selected to be 500m and following were the output parameters obtained for a bi-directional communication as listed in table III.

TABLE III

Output parameter values for bi-directional communication for a distance of 500m.

Parameters	Transmitter to Receiver	Receiver to Transmitter
Gain (dB)	-2.988	-3.561
Noise figure (dB)	2.988	3.561
Quality Factor	15.2791	18.8933
BER	5.27E-33	6.48E-41
Output OSNR (dB)	103.79	106.72
Output Signal	3.798	6.72

The eye pattern diagram obtained from the transmitter to the receiver for a bi-directional communication over a distance of 500m is as shown in figure 5.

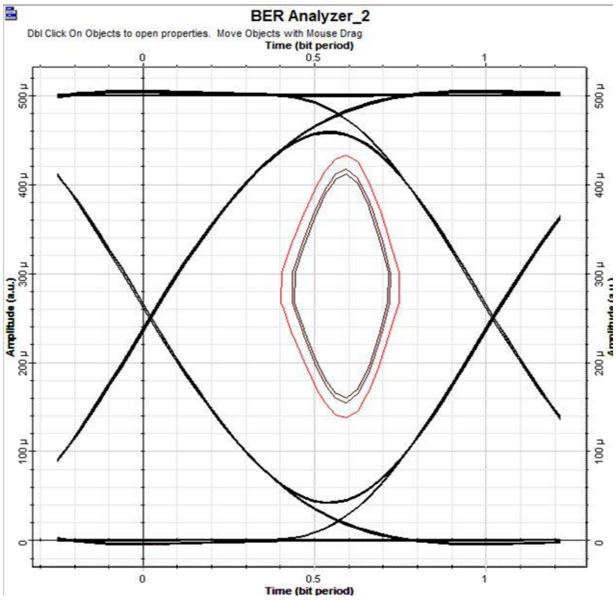

Fig. 5: Eye Pattern diagram for communication from transmitter to receiver

The eye pattern diagram obtained from the receiver to the transmitter for a bi-directional communication over a distance of 500m is as shown in figure 6.

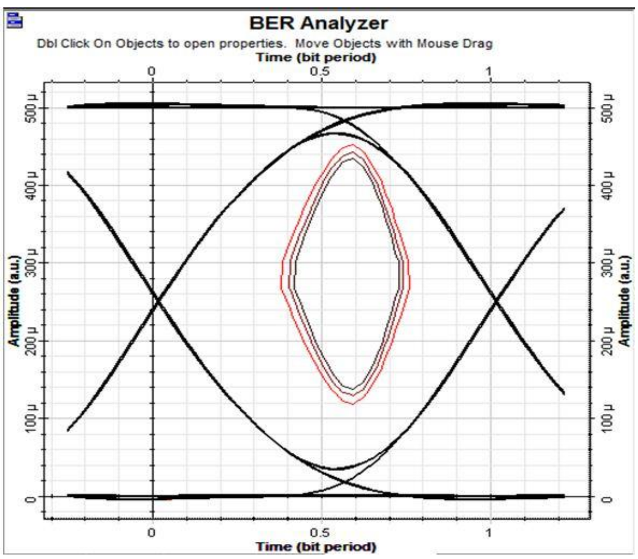

Fig. 6: Eye Pattern diagram for communication from receiver to transmitter.

III. COMPLETE HOSPITAL PON

Hospital management is the management and administration of public health systems, health care systems, hospitals and hospital networks. The hospital scenario was first designed on an application called Sketchup and then simulated using Optisystem. The hospital building was considered to be a two floor building with administration included.

The entire simulation was done in stages by creating subsystem at each stage [10], [11].

Figure 7 shows the complete hospital design which consist of administration, floor wise model, and analyzers as subsystem.

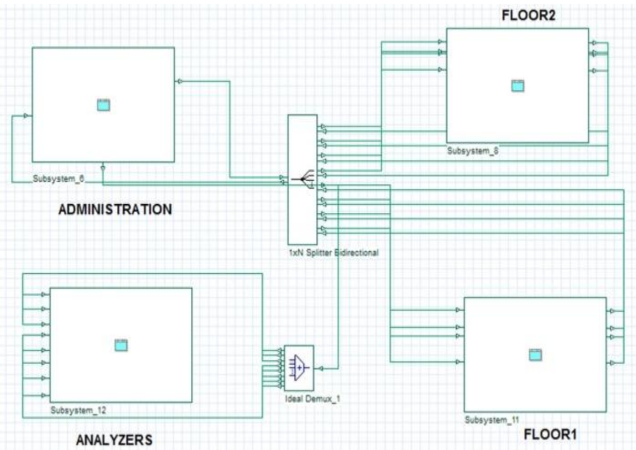

Fig. 7: Entire Hospital Optical Communication System.

Figure 8 shows the administration subsystem which is the transmitter side for the hospital where all the data from different wards and transmission of data to all the wards is done.

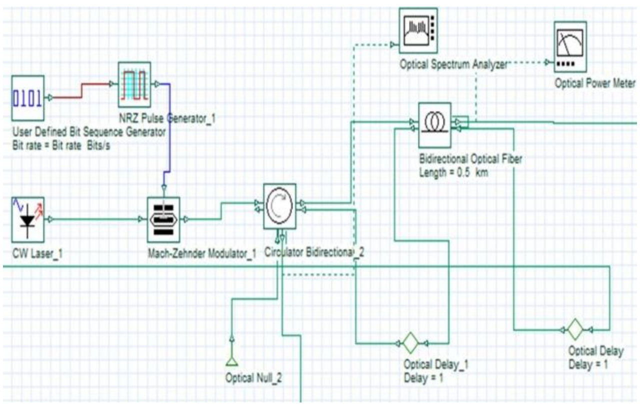

Fig. 8: Administration Subsystem.

Figures 9 and 10 show the floor wise model where frequency division multiplexing was used as a result each wards has their own frequency of operation [12], [13].

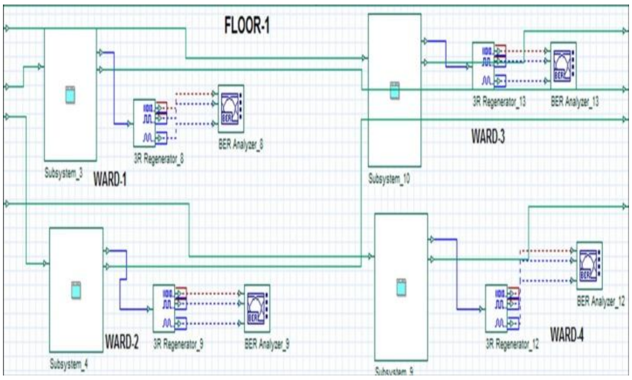

Fig. 9: Floor-1 Subsystem.

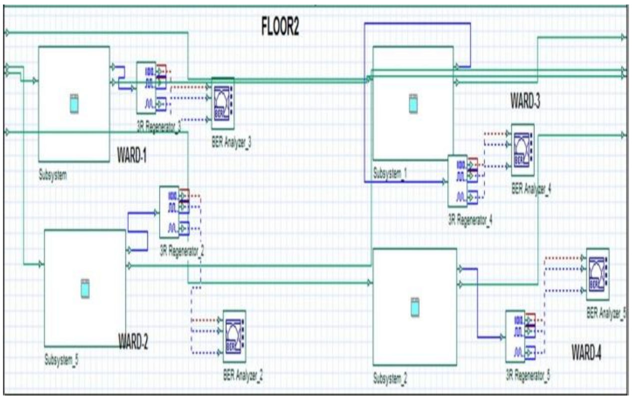

Fig. 10: Floor-2 Subsystem.

Figure 11 shows the analyzers of all the wards of receiver and this analyzers are present at the transmitter side to analyze the data received.

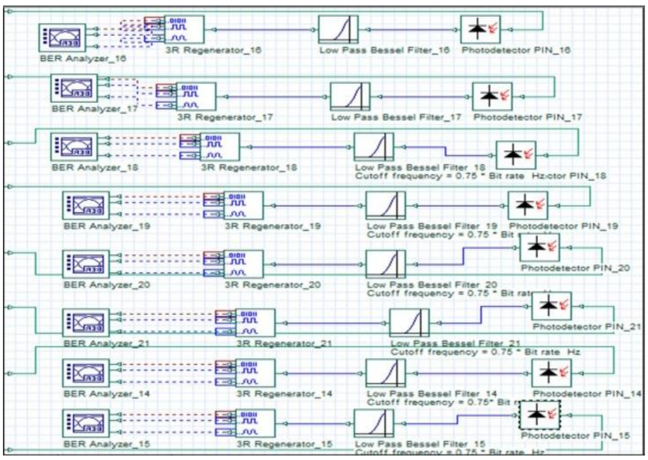

Fig.11: Analyzer Subsystem.

For the hospital scenario the data rate was selected to be 512Mbps using bi-directional communication and the following simulated parameter for various wards are listed in table IV.

TABLE IV

Output parameters for hospital scenario using bi-directional communication for data rate of 512Mbps.

Ward No.	Quality factor	BER
1	20.515	3.20E-36
2	14.75	2.98E-38
3	14.415	1.36E-35
4	13.46	3.79E-46
5	13.34	5.14E-32
6	13.256	9.58E-29
7	14.256	2.68E-30
8	16.373	4.65E-31

The data rate was increased to 1 Gbps and using the same bi-directional communication the following parameters were simulated as listed in table V.

TABLE V

Output parameters for hospital scenario using bi-directional communication for data rate of 1Gbps.

Ward No.	Quality factor	BER
1	24.575	1.07E-33
2	17.625	7.74E-40
3	17.175	1.60E-36
4	29.134	6.44E-42
5	24.814	3.11E-39
6	16.215	1.22E-45
7	15.966	9.30E-48
8	10.515	4.01E-36

The data rate was further increased to 2.5 Gbps and the parameters simulated are listed in table VI.

TABLE VI

Output parameters for hospital scenario using bi-directional communication for data rate of 2.5Gbps.

Ward No.	Quality factor	BER
1	24.158	2.95E-39
2	28.279	3.03E-26
3	28.132	1.90E-34
4	28.427	1.48E-48
5	14.926	1.10E-51
6	17.190	1.53E-40
7	15.058	2.97E-50
8	13.454	2.71E-35

The data rate was increased to 5 Gbps and using the same bi-directional communication the following parameters were simulated as listed in table VII.

TABLE VII

Output parameters for hospital scenario using bi-directional communication for data rate of 5Gbps.

Ward No.	Quality factor	BER
1	20.797	1.59E-27
2	18.478	9.17E-18
3	19.185	1.66E-20
4	14.769	1.68E-28
5	14.769	1.62E-30
6	17.066	4.62E-26
7	17.622	8.53E-20
8	16.548	1.49E-24

The two hospitals were considered at 50 km apart. As the distance is 50 km an amplifier was required to increase the gain of signal. Both scenarios were considered, one without amplifier and the other with amplifier between the two hospitals [14], [15].

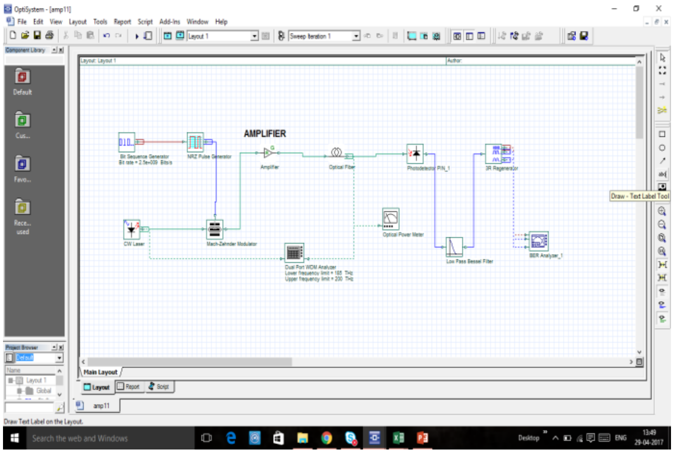

Fig. 12: Amplifier System

Basic communication system was implemented in Optisim with and without amplifier for verification of gain. The output parameters are listed in table VIII.

TABLE VIII

Output parameters for basic communication system

Parameters	Without amplifier	With amplifier
Gain	-9.89	11.67
OSNR	86.52	52.68
BER	5.85E-24	8.61E-32
Q factor	10.02	11 .67

Hospitals having branches in different cities can also be connected using optical fiber and the scenario has been designed in Optisystem.

The output parameters for communication between two hospitals with and without amplifiers are listed in table VIII. The distance between two hospital branches have been kept as 50 Km. The output parameters thus obtained are listed in table IX.

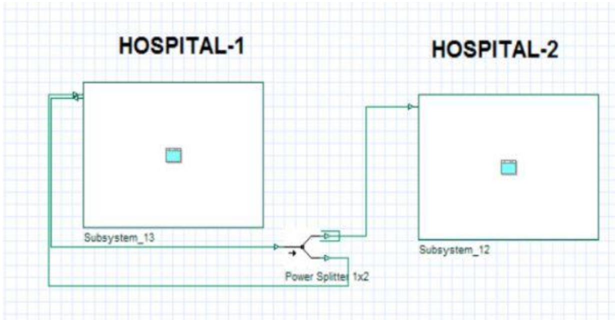

Fig. 13: Inter Hospital Communication Network.

TABLE IX

Output parameters for communication between two hospitals

Parameters	Without amplifier	With amplifier
Gain	-6.01	9.56
OSNR	93.58	69.68
Input Power(dBm)	19.58	20
Output Power(dBm)	13.46	29

IV. CONCLUSIONS

In this paper the design of Passive Optical Network for hospital management have been designed for a hospital scenario where bi-directional transfer of data is carried out and also communication between hospitals far away from each other (In this case 50Km apart) is possible. BER analyzer, Optical power meter and WDM analyzers are used to analyze the network. Also the desired results are obtained and the relative conditions like BER and quality factor were verified.

In this design data rate up to 5Gbps was achieved, as beyond this results in distortion of signal. Thus the future scope could still include modification of parameters or new systems could be introduced to improve its performance to achieve data rate up to 10Gbps. Also voice over cable (fiber optic cable) could be achieved in this case. The system can be optimized to the fullest possible.

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