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Design and Implementation of Gigabit Passive Optical Network

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Abstract: The steady increase in the digitisation of every field created a desperate demand for broadband services and the consequent increase in the volume of generated traffic in our communication networks have motivated the need to make access networks in our rural territories too. This paper aims to explain the design and implementation of a passive optical network. The main idea of this paper is to build an optical fiber based access network for broadband connectivity to the rural areas. This will allow us to implement this network modal for expansion of reach of high speed broadband services in future.
Keywords: Fiber to the Home (FTTH), Passive optical network (PON) , Optical network terminal (ONT), Optical line terminal (OLT), Gigabit Passive optical network (GPON), broadband, OTDR

I. INTRODUCTION

The optical fiber is the most advanced transmission medium and the only one capable of supporting next generation networks and services. The main advantages of having a last mile of optical fiber are many: greater speed, higher bandwidth, and longer distance from the central to the subscriber, resistance to electromagnetic interference, higher security, and reduced signal attenuation. Moreover, the fact of using PON technology assumes the elimination of active components outside the plant such as repeaters and optical amplifiers and therefore decreasing the initial investment, reducing power consumption, lesser points of failure.

Passive optical network (PON) access network is a point-to-multipoint, fiber to the home network architecture in which unpowered optical splitters are used to make a single optical fiber to serve multiple customers, typically 32–128 [1]. PON networks exploit the low attenuation of optical fiber cable (0.2–0.4 dB/km) and high bandwidth (>30,000 GHz) of single mode optical fibers [2]. These capabilities of PON give commonly more data transmission than as of now accessible networks with existing broadband advances. Also, PON based FTTH networks can give different communication services viz. voice, information and video from one platform [3]. Due to these advantages now most of the telecom operators use FTTH network as optical fiber access network. For a GPON based network maximum of 128 ONTs (Optical Network Terminal) can be included with maximum reachability of 60 km and maximum distance between two consecutive ONTs (Differential fiber distance) of 20 km as per G.984.6 ITU-T specification [4]. GPON uses data transmission speed of 2.44 Gbps in downstream and 1.24 Gbps in upstream. Broadcasting or continuous transmission for downstream and TDM technique for upstream are used as transmission method.

In this paper, the approval of proposed design of network is done on the bas is of Link loss Budget and cost. The results shows that the continuity of newly laid optical fiber cable from OLT to ONTs and received power levels falls within optical power loss plan and the cost is lowest.

This paper organized with different sections like Basic Components of GPON access network, design and Implementation with flowchart, results, and finally with the conclusion.

II. BASIC COMPONENTS OF GPON ACCESS NETWORK

A Gigabit Passive Optical Network (GPON) is generally having P2M (point to multipoint) network topology with active and passive components. Optical splitter or coupler along with every component in the transmission section outside the plant is passive component. Active components are only at CO and at ONTs locations. Fig.1 shows GPON access network architecture depicting its components.

A. Optical Line Terminal OLT

The Optical Line Terminal (OLT) is the most important element of the network and Master of the access network and it is generally placed in the Local Exchange where already optical fiber based backbone network available [5]. The important functions that OLT delivers are traffic scheduling and control, buffer control and dynamic bandwidth allocation [6]. OLTs operate using redundant DC power supply (-48VDC) and have at least 1 Line card for connecting the access network to backbone network , 1 System Card for on-board configuration, and 1 or more GPON cards. GPON cards includes a number of

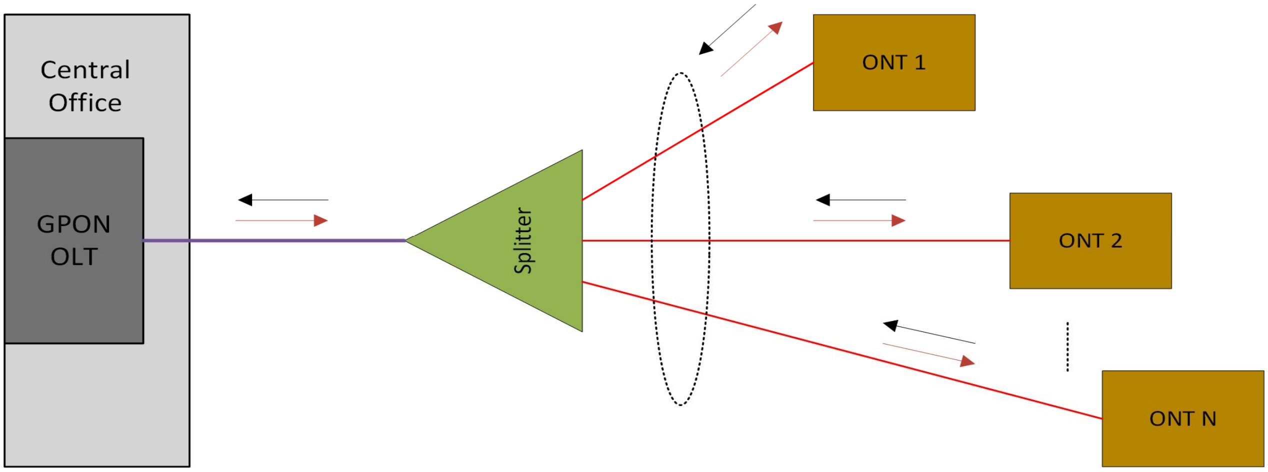

Fig. 1 GPON Access Network Architecture

GPON ports. Ports are connected with input of splitters in P2M topology. The transmission mode from OLT to ONT is broadcasting [4].

B. Optical Splitter

In order to expand the access network, it will used optical splitters or dividers. Splitters can split one or two fibers into N number of outgoing fibers uniformly or combine light from N number of fibers to one or two over a broad spectral range. This enables feeding of each fiber by many fibers and finally many more users. Since the splitters involve a significant loss of Optical power in relation to other network components, the design of a network must be carefully balanced between: high branching fibers, distances to customers and powers managed by equipment, so that meet the main specifications. Splitters need to have characteristics like: Wide spectral range, minimum insertion loss and uniformity, smaller dimension, and high reliability.

C. Optical Network Terminal ONT

The ONT (Optical Network Terminal) is the last element of our network. This in-charge of optical-electrical conversion oriented to the subscriber obtains the required services. It will be placed in user's home ending the optical fiber and provides the user interfaces. ONTs are connected to the OLT by optical fiber cable and no active elements are present in between the link. As it has talked about, the ONT is an active device, in general, it must be the same manufacturer as the OLT, although it is working to achieve interoperability between manufacturers, which would open the market and lower prices.
The transceiver in the ONT is the physical connection to communicate between the customer and the OLT. Media Access Controller (MAC) controls the Burst mode upstream traffic in an systematic manner and enables that no collision occur in data transmission from different ONTs in Upstream mode[5]. ONTs are basically optical to electrical signal converters that offer RJ11, RJ45, and F-Series connectors to provide connection to many devices. These devices are available in many configurations up to 24 ports. ONTs are available with AES encryption, and batteries for operability in the event of a mains power failure. GPON uses Dynamic Bandwidth Allocation that is it dynamically allocates the bandwidth on the basis of traffic available in the T-CONT. If the ONT requests for the number of packets waiting in T-CONT, OLT assigns the bandwidth. If there are no requests from ONT, then OLT assigns the bandwidth to other T-CONT which have packets waiting in T-CONT. If an ONT has a high traffic OLT can assign multiple T-CONTS to that ONT [7].

III.DESIGN

To design the OFC Link, By Software and Sitting in AC room planning does not work, each root and ONT locations is surveyed physically, noted down all the details of feasible routes and then planned precisely using as per available data and experience. Any single standards cannot be applied as each country has its own unique soil strata. The design of GPON includes the steps involved in the Route survey stage , preparing a Single Line diagram and drawing a port diagram ,splitter allocation design to each route, link loss calculation, Optical Time Domain Reflectometer (OTDR) testing and power meter tes ting . The flow chart showing the each stage of designing an OFC Link for access network based on GPON is shown in Fig.2. The shortest route and optical power budget are the main two factors taken in consideration while designing.

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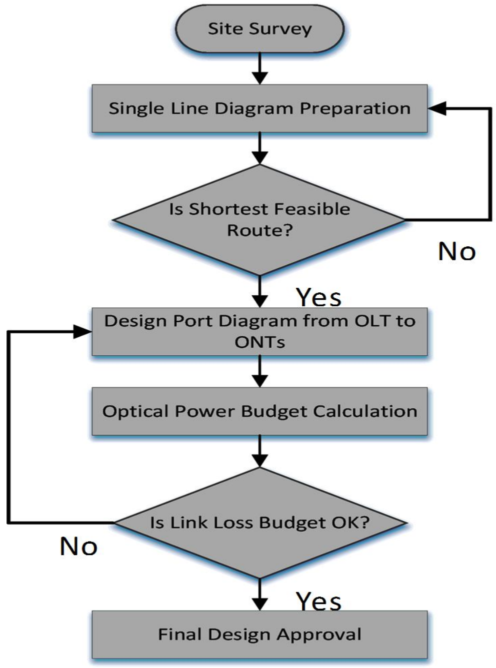

Fig. 2 Design Steps for GPON Access Network

A. Link Loss Budget Calculation for the Proposed Route

The link loss budget is key to a fiber optical communication system. It refers to the amount of loss that a fiber cable plant should have for reliable communication link. The calculation of a fiber optic system link budget is done by given Equation 1.

Link Loss Budget = [fiber length (km) × fiber attenuation per km] + [splice loss × # of splices] + [splitter loss] + [connector loss × # of connectors] + [safety margin] ………… (1) [8]

Using equation 1, the theoretical calculation of link loss budget for all ONTs in different routes are given in Table 1.

Table I
Theoretical Calculation of the link Loss Budget

ONT Name	Cable length from OLT to ONT	No. of splices	Splice loss	Splitter loss	Cable attenuation	Total cable loss	FDT connector loss	Total Route Loss	Trans Power (dBm) at OLT PON Port	Receiver Level
ONT1	603	2	-0.2	-7.4	-0.22	-7.82	-1	-8.82	1.5	-7.3
ONT2	3267	3	-0.3	-7.4	-1.19	-8.89	-1	-9.89	1.5	-8.4
ONT3	8679	6	-0.6	-7.4	-3.17	-11.17	-1	-12.17	1.5	-10.7
ONT4	11418	7	-0.7	-7.4	-4.17	-12.27	-1	-13.27	1.5	-11.8
ONT5	11428	3	-0.3	-7.4	-4.17	-11.87	-1	-12.87	1.5	-11.4
ONT6	13562	4	-0.4	-7.4	-4.95	-12.75	-1	-13.75	1.5	-12.3
ONT7	14866	5	-0.5	-7.4	-5.43	-13.33	-1	-14.33	1.5	-12.8
ONT8	17348	6	-0.6	-7.4	-6.33	-14.33	-1	-15.33	1.5	-13.8
ONT9	27175	11	-1.1	-3.7	-9.92	-14.72	-1	-15.72	1.5	-14.2

From the Table 1, it is being observed that the nearest ONT has optical loss of -8.82 dB and the farthest ONT has -15.72 dB. The range of link loss budget is optimal and safe, hence the design can be used for implementation.

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IV. IMPLEMENTATION

Any technological project should be implemented as per already approved design and a predefined process for every steps. This is very crucial to projects in which a mixer of engineering based activities are involved, where an error in earlier stages might lead to an enormous error in the final stage and project may lead to failure or a poor quality.

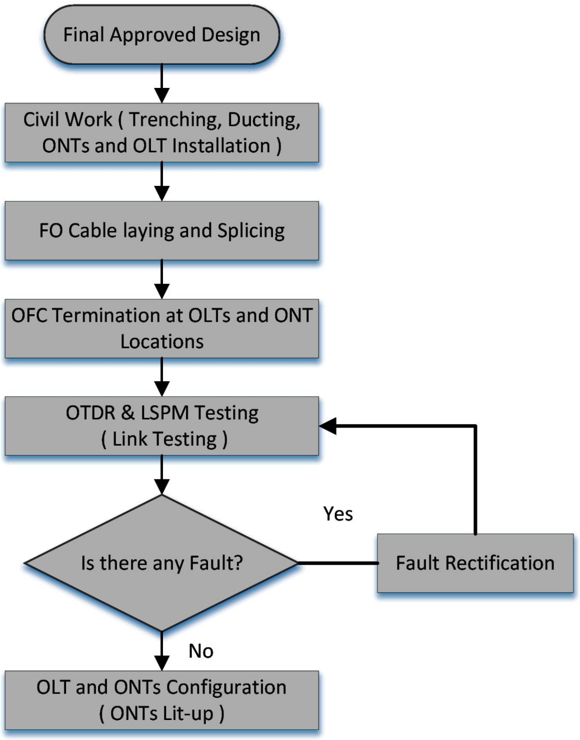

Fig. 3 Implementation Steps for GPON Access Network

OFC based network projects are amongst such projects where there are a combination of civil and technical activities. Therefore, a sincere inspection is given during this Project implementation. Fig.3 shows the major steps involved in implementation of GPON access network.

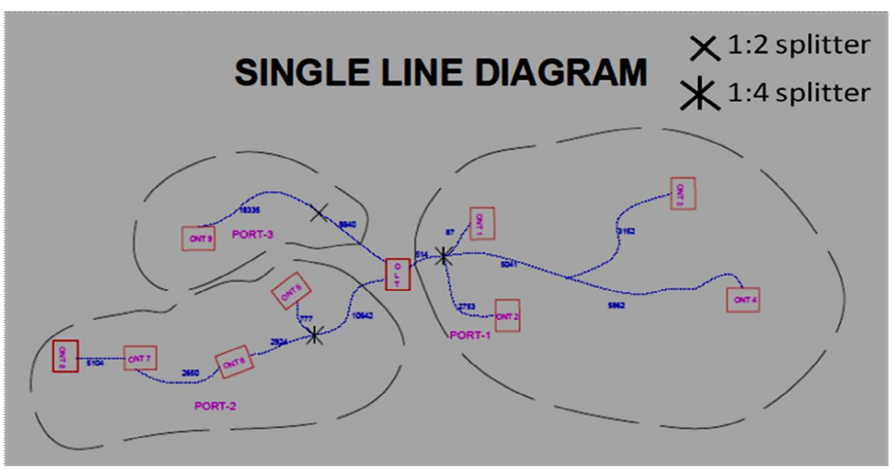

Fig. 4 Single line diagram

Fig. 4 shows the single line diagram that depicts the feasible routes for fiber laying from OLT to all ONTs locations. It can be seen from the figure that there are three different routes for covering all ONTs.

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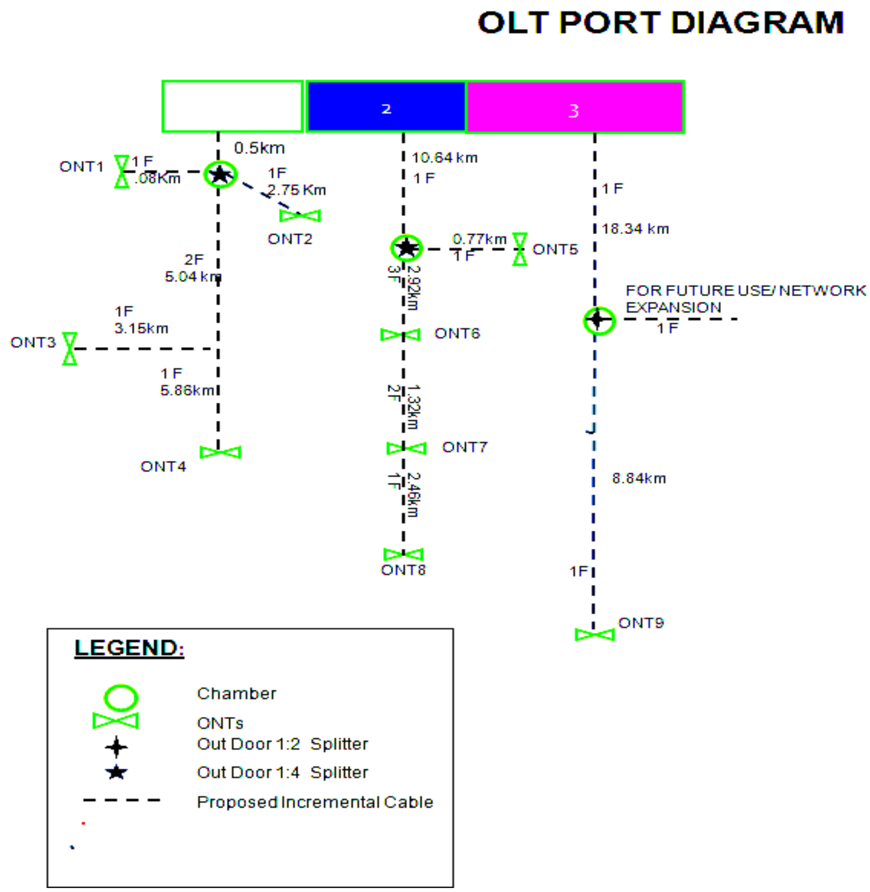

Fig. 5 OLT Port Diagram

Fig. 5 shows the port diagram of implemented GPON access network. It gives information about the distance between ONTs and OLT as well as port connectivity for all ONTs. The approved design leads to implementation of the GPON access network. We have designed the FO network to connect 9 villages by high speed broadband. During implementation of each steps of the project we have given a due attention to the quality of work so the future of this project could be reliable and durable. In the last step of the project we adopted two methods for testing the end to end completed work. These are OTDR testing and laser source/power meter testing. Optical Time Domain Reflectometer OTDR is used for checking the health and continuity of the newly laid OFC and to find exact fault location in the OFC link. Laser source/power meter is used for the measurement of exact optical power loss between OLT to ONTs.

V. RESULTS

Having explained the whole design, it just needs to get the results that will decide if the design works or not, and therefore whether constructed OFC link will be feasible to put live network traffic. The results that are going to expose are the Optical Time-Domain Reflectometer trace, which will show whether OLT to ONT OFC link is through or not and the decision threshold optical power as a function of the Total end to end Link loss. Let's see first OTDR Trace results from ONT locations and later Link loss results.

Here we are presenting OTDR trace of farthest ONTs location of all port to assume that whole implemented OFC link are healthy. We will connect OTDR to ONT4 location and test newly laid optical fiber cable connecting ONT4 to OLT. Fig 6 shows OTDR trace, length of the fiber is 11.4 km which is equal to the distance of OLT to ONT4. This results of trace reflects that newly laid fiber is quite healthy and through to link ONT4 from OLT. At distance of approximately 10.9 KMs towards OLT there is high loss in OTDR trace graph which is very much normal and expected because of 1:4 splitter used. . Fig 7 shows OTDR trace, length of the fiber is 17.34 km which is equal to the distance of OLT to ONT4. This results of trace reflects that newly laid fiber is quite healthy and through to link ONT8 from OLT. At distance of approximately 6.70 KMs towards OLT there is high loss in OTDR trace graph which is because of 1:4 splitter used at this location.

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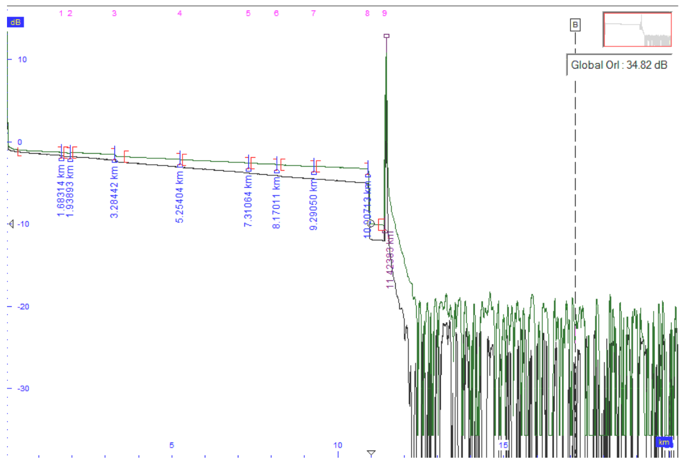
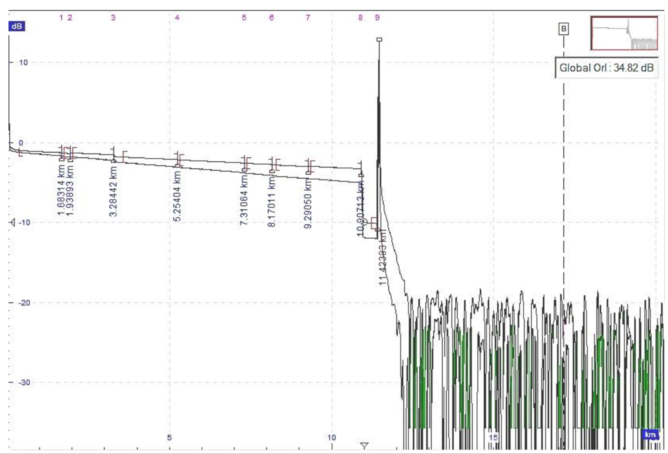


Summary

File name	Wavelength (nm)	Total loss (OTDR) (dB)	Link ORL (dB)	Total length (km)	Splice max. (dB)
ONT 4.m...	1310	10.973	34.40	11.41872	6.814
ONT 4.m...	1550	9.182	34.82	11.42383	6.669

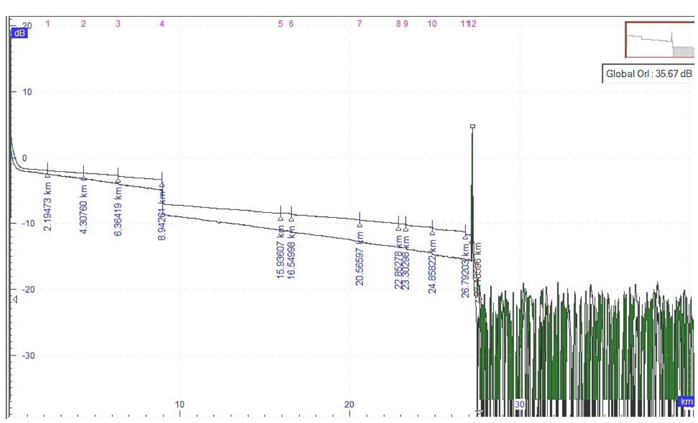
Fig. 6 OTDR Trace & summary for ONT4



Summary

File name	Wavelength (nm)	Total loss (OTDR) (dB)	Link ORL (dB)	Total length (km)	Splice max. (dB)
ONT 8.m...	1310	14.982	34.08	17.34806	7.088
ONT 8.m...	1550	13.010	35.40	17.35829	7.155

Fig. 7 OTDR Trace & summary for ONT8



Summary

File name	Wavelength (nm)	Total loss (OTDR) (dB)	Link ORL (dB)	Total length (km)	Splice max. (dB)
ONT 9.m...	1310	14.005	35.60	27.17573	3.725
ONT 9.m...	1550	10.282	35.67	27.18596	3.694

Fig. 8 OTDR Trace & summary for ONT9

Port 3 is connected with a 1:2 splitter because ONT9 location is almost 27 kms far away from OLT, due to this high distance fiber loss and splice loss will be higher. Hence to minimize the loss we used 1:2 splitter. The second output of the splitter kept reserve for future network expansion or may be during any fault correction. Fig. 8 shows OTDR trace, total length of the fiber is 27.14 km which is equal to the distance of OLT to ONT9. This results of trace reflects that newly laid fiber is quite healthy to link ONT9 from OLT

Table II
End To End Link Loss Testing Results By LSPM Method

S.No.	ONT Name	Section Length in KM	Receive Level (dB)		Link Loss	
			1310 nm	1550 nm	1310 nm	1550 nm
1	ONT_1	0.603	-16.72	-16.15	-8.26	-7.99
2	ONT_2	3.269	-16.63	-15.63	-8.17	-7.47
3	ONT_3	8.679	-18.63	-17.63	-10.17	-9.47
4	ONT_4	11.418	-19.84	-17.78	-11.38	-9.62
5	ONT_5	11.434	-20.42	-18.29	-11.96	-10.13
6	ONT_6	13.567	-21.37	-19.05	-12.91	-10.89
7	ONT_7	14.872	-22.31	-20.53	-13.85	-12.37
8	ONT_8	17.358	-23.05	-21.75	-14.59	-13.59
9	ONT_9	27.186	-23.8	-21.53	-15.34	-13.37

The Table II shows the received optical power in LSPM tests. It is being observed that the loss of each links is less than the receiver threshold value by a margin of more than -5dB.

VI. CONCLUSION

This paper presented a design and implementation model of GPON based optical fiber cable access network for 9 villages including future expansion. Practical approach and field experience is the main considerable point in this model of network. The design procedure followed Practical and field experience approach, in which the size of the network and its components is chosen after analysing the number of locations and the geographical separation. OFC link design have to be based on the physical survey of each port. Software or AC room sitting design causes big hurdle in implementation and waste a lot of time and cost when some roots needs to be redesigned to avoid certain physical or conditional obstacle. In order to get final approval of the design, the optical Link loss budgets is calculated for all locations, and the results showed that the maximum power loss was -15.34 dB which is lower than the receiver threshold limit. It is proven that the above model for access network based on GPON technology can be used to connect all villages through high speed broadband.

VII. ACKNOWLEDGEMENT

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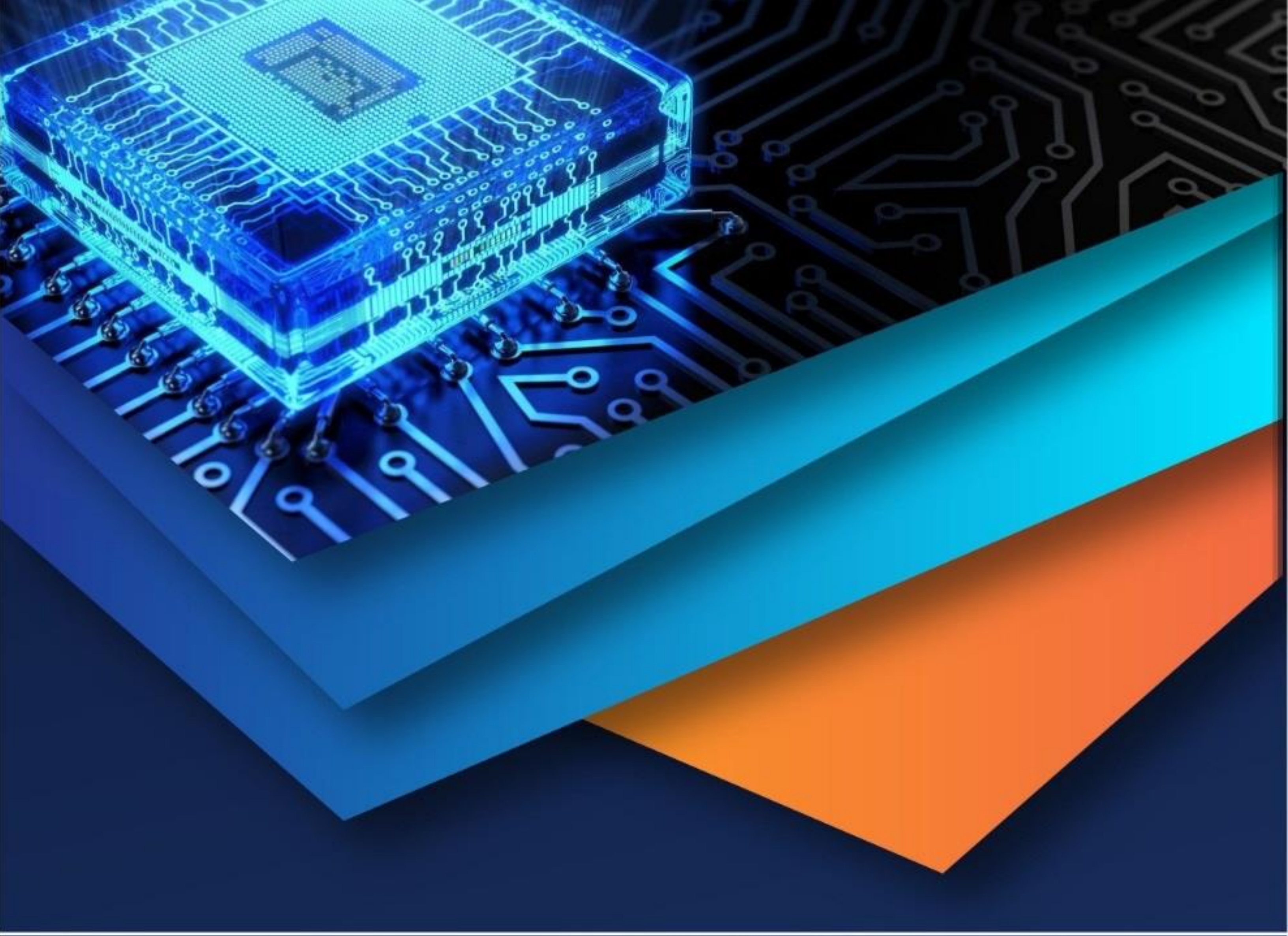
REFERENCES

[1] Rajneesh Kalera and R.S. Kalerb, “Simulation of Fiber to the Home at 10 Gbit/s using GE-PON architecture,” Optik: Elsevier B.V, pp. 1362-1366, 2011.
[2] Salah Al-Chalabi, “Optically Powered Telephone System over Optical Fiber with High Service Availability and Low Risk of Investment in FTTH Infrastructure,” IEEE Communications Magazine, August 2012.
[3] Jagjit Singh Malhotra, Manoj Kumar and Ajay K.Sharma, “Low cost solution to high capacity 32 × 32 channel FTTH duplex link employing triple play services,” Optik: Elsevier B.V, pp. 93-96, 2014.
[4] ITU-T G.984 Gigabit Passive Optical Network Specifications.
[5] Jani Saheb Shaik, “FTTH deployment options for telecom operators,” www.sterlitetechnologies.com.
[6] Yinghui Qiu, “Availability estimation of FTTH architectures based on GPON,” in proc. IEEE 2011 7th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1-4.
[7] Katla, Satyanarayana, and Abhinov Balagoni. "Technological and Cost based Analysis of Future-Proof Fiber Access Passive Networks: GPON and WDM PON." arXiv preprint arXiv: 1308.5356 (2013).
[8] M .M. Al-Quzwini, “Design and Implementation of a Fiber to the Home FTTH Access Network based on GPON”, International Journal of Computer Applications, vol.92, no.6, April 2014.



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