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A Study on Development of Optical Protection Socket for Optical Customer Premises Network

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광가입자망에서의 광절체 접속장치 구현에 관한 연구

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ABSTRACT

In this paper, the optical protection sockets(OPSs) improving the reliability of customer premises networks have been studied. The hybrid-typed OPS units utilizing passive optical fiber components such as 2x1 optical couplers, 1x2 optical splitters, and active 1x1 optical switches, have been constructed. For optimizing switching time to minimize data loss, the electrical controller was designed to adjust switching time-delay, and the best switching performances have been observed from the coupling experiment with STM-1(155Mbps) data signal. The numerical results of link-power budget analysis show the maximum distance 11.88Km between ONUs, and the maximum bypassing ONU numbers are 2 units.

要 約

광가입자망의 신뢰도 향상에 매우 중요한 광접속장치 구현에 관해서 연구하였다. 2×1 광결합기, 1×2 광분배기와 같은 광섬유 수동소자와 1×1 광섬유 스위치를 이용하여 하이브리드형 광절체 접속장치를 구현하였다. 스위칭 지연시간의 최적화를 통해서 데이타 손실을 최소화할 수 있도록 제어부분을 설계하였으며, STM-1(155Mbps)급 신호와의 연동실험을 통해서 그 결과를 검증하였다. 링크 파워분석 전산모의 실험을 통해서 ONU간의 최대거리는 11.88Km, 2개의 ONU를 바이패스할 수 있음을 확인하였다.

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Ⅰ. Introduction

In accordance with a tendency of high speed and broadband of communication networks, an optical subscriber network based on optical fiber transmission technologies, has been studied actively by many researchers in global area.[1]

Especially, under the concepts such as FTTO, FTTC, and FTTH, network architectures and communication methods between telephone office and subscriber congestion area have been studied intensively. On the other hand, the networks among subscribers have been relatively less investigated because of the diversity of services requested by each subscriber and cost problem, etc. However, it is getting important to study about subscriber networks according to the global B-ISDN tendency of communication networks. This kind of network is classified as customer premises network(CPN) and it is belived that the cost and technology for its construction will have a great effect on the early realization of B-ISDN.[2],[3]

A customer premises network provides interface fuctions between a broadband integrated service digital network(B-ISDN) and user terminals, and handles the protocol requirements of the interface to the user terminals and those of the interface to the network termination. There are various fiber-based architectures such as star-typed, bus-typed, hybrid-typed, and ring-typed. The hybrid-typed architecture suggested by Bellcore as shown in Fig. 1 was considered in this paper.[4] Key features of this network are the use of optical fiber as a transmission medium and a hybrid architecture, namely a broadcast bus for the downstream and a looped bus for upstream traffic. In this upstream architecture, the optical protection socket(OPS) which is capable to bypass to the next ONU(Optical Network Unit) when the current ONU is damaged, is necessary to guarantee the service survivability.

Therefore, an OPS(Optical Protection Socket) unit which plays an important role for the reliability of CPN has been designed and constructed in this work. Especially, the control part monitoring several situations for switching has been considered intensively for the practical system applications.

In section Ⅱ, the operation principles and design of hybrid OPS unit were mentioned. The power budget simulation procedures were described to verify whether the OPS unit guarantees the looped-bus stream in section Ⅲ. In section Ⅳ, the constructed prototype of OPS and the experience with STM-1 level were mentioned. Finally, conclusion was given in section Ⅴ.

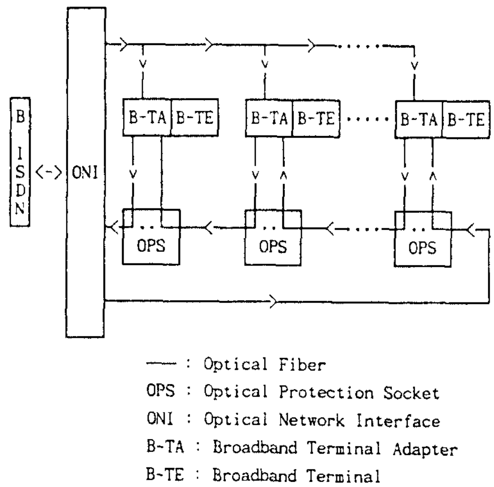

Figure 1. The CPN architecture proposed by Bellcore

Ⅱ. Design of OPS Structure

As communication networks have been progressed to B-ISDN, the importance of an optical subscriber networks has been recognized so much, and various CPN architectures were proposed. The hybrid-bus architecture, shown in Fig. 1, consists of two unidirectional buses operating at different bit-rates. They are terminated at the broadband network terminations (BNT), which serves as a gateway between the B-ISDN and the CPN. The downstream signal is broadcast on a about 600Mbps bus, and each broadband terminal adaptor (BTA) filters out only the information destined to it. In the upstream direction, an about 150Mbps signal is transmitted on the looped bus and is regenerated at every BTA connected to it. Intra-CPN communication among terminals is provided via the BNT. The OPS improves the reliability of the upstream looped-bus. Namely, in the event of a terminal failures due to either electronic problems, power loss or disconnection, the associated OPS will automatically bypass the optical signal to the next BTA, thus preserving the continuity of the looped bus.

Fig. 2 shows the details of the OPS structure proposed in this study. The OPS has been designed with 1×2 optical fiber splitter, combiners and 1×1 optical switches, and electronic monitoring part as the previous step of the planar optical integrated

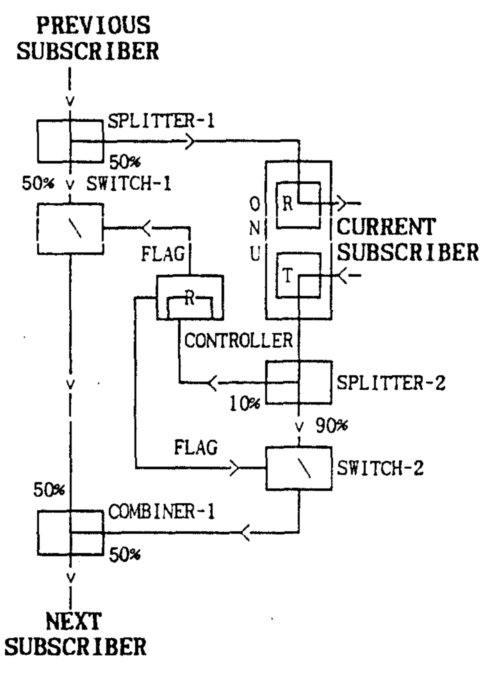

Figure 2. The schematic diagram of OPS

unit. Various system requirements were considered for the practical applications. The optical components which are consistent with standard device performance recommended by bellcore, were chosen.[5] The both situations under the restoration to normal state as well as the malfunction of ONU can be controlled by the OPS. Also, to avoid the optical data loss and the collision during the switching behaviour, the electronic unit was designed to adjust the delay time.[6],[7]

Optical signals transmitted from the previous subscriber are terminated at the looped-bus inlet (at the top of the Fig. 2), whereas optical signals to the next subscriber are sent through the looped-bus outlet (at the bottom of Fig. 2). The ONU on the right of the Fig. 2 are used to interface with each subscirber (corresponding to BTA in Fig. 1). In series with the looped bus is a low-power, electrically activated optical fiber switch. The switch is designed so that its relaxed state (unpowered) is to be transparent to light on the looped bus, and in its powered state it is opaque and thus blocks signals on the looped bus. The looped bus has an optical 1×2 splitter attached to it which allows a half amount of light to be removed from the input port of the OPS and applied to the subscriber's optical receiver in ONU. The excess power loss introduced by the OPS is not significant because upstream optical signals are regenerated at every subscriber's ONU. The OPS also has a tap at its output port to allow optical power from the local ONU transmitter to be injected onto the looped bus.

Two optical switches(1×1) were used for counter-switching. The operation procedure of the OPS is as follows. When the situations such as breakdown or optical power degradation of current ONU are detected by the control part, the control signal is sent to the optical switch 1 immediately for closing it and after 0.5ms time delay, the other control signal is given to the optical switch 2 for opening it. With the above preceeding, the optical protection is performed to bypass the current damaged ONU and the optical data from the previous stage is transmitted to the next stage without interruption of information flow. Here, the 0.5ms time delay corresponds to the optical transition time of the optical switch. In the other side, when ONU is restored to the normal state, the control signal is applied to the optical switch 2 immediately for closing it, and the other control signal is sent to the optical switch 1 for opening it after the the same delay time. In our design, the delay time can be suitably controlled even for several different situations and the data collision problem in coupler 3 can also be overcomed.

Ⅲ. Simulation of OPS Performance

1. System Power Budget Simulation

Several optical components consisting of the proposed OPS unit have insertion and attenuation losses. The power budget simulation has been carried out to know whether the proper components and design parameters were chosen such that the OPS unit was capable of doing stable operation. Let the 2×1 optical coupler insertion loss be L_1(dB/ea), the 1×2 optical splitter insertion loss be L_2(dB/ea), the optical switch insertion loss be L_s(dB/ea), the connector insertion loss be L_{CN}(dB/ea), and the attenuation loss of optical fiber per unit length be L_f(dB/Km).[8]

• PATH 1 : optical transmitter 1 of previous stage → optical splitter 2 of previous stage → optical switch 2 of previous stage → optical coupler 3 of previous stage → optical splitter 1 → optical switch 1 → optical coupler 3 → optical splitter 1 of next stage → optical receiver 1 of next stage

$$P_{T1}=n_1L_1+n_2L_2+n_sL_s+n_{cn}L_{cn}+l_fL_f(\text{dB}) \quad (1)$$

Where n_1, n_2, n_s, n_{cn}, and l_f are the number of coupler, splitter, switch, connector, and fiber length. The path 1 corresponding to Fig. 3 shows the data flow path when the current stage ONU is out of order.

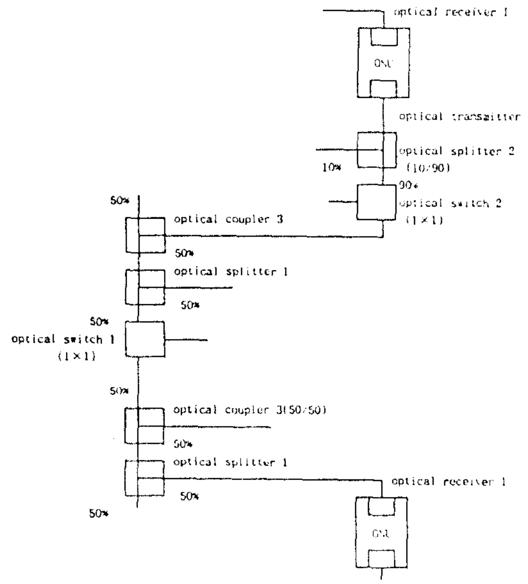

Figure 3. The block diagram of path 1 for power budget simulation.

• PATH 2 : optical transmitter 1 of previous stage → optical splitter 2 of previous stage → optical switch 2 of previous stage → optical coupler 3 of previous stage → optical splitter 1 → optical receiver 1

$$P_{T2}=n_1L_1+n_2L_2+n_sL_s+n_{cn}L_{cn}+l_fL_f(\text{dB}) \quad (2)$$

The path 2 corresponding to Fig. 4, shows the normal transmission of the optical data between the current ONU and the next ONU without the malfunction of any ONU.

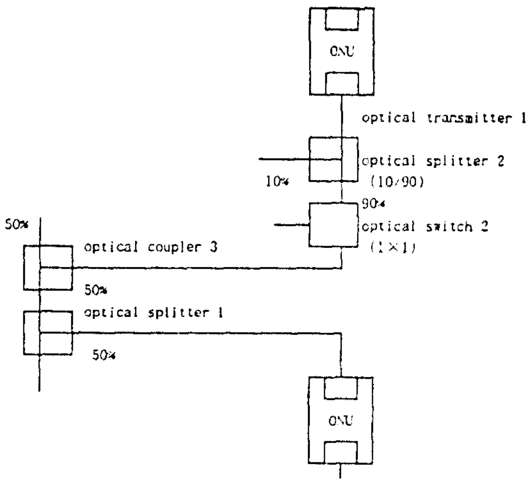

Figure 4. The block diagram of path 2 for power budget simulation.

- PATH 3 : optical transmitter 1 → optical coupler 2 → optical receiver 2

$$P_{T3} = n_2 L_2 + n_{cn} L_{cn} + l_f L_f \,(dB) \quad (3)$$

The path 3 shows the optical path passing to the monitoring circuit for detecting the situation of current ONU, as shown in Fig. 5.

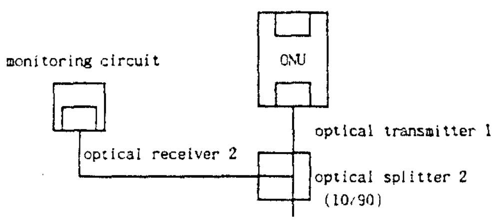

Figure 5. The block diagram of path 3 for power budget simulation.

Let the transmitter power be P_S, and the receiver sensitivity be P_R, then relationships among P_S, P_R, P_T result in

$$P_T + M < P_s - P_R \,(dB) \quad \text{or} \quad P_R < P_s - P_T - M \,(dB) \quad (4)$$

Where the system margin M for maintaining the stable system performance, is about 6dB in general. The margins are used for all power or loss variations that are not accounted for in the indivisual component parameters. The insertion loss for the 1×2 optical splitter(1 : 9) including the intrinsic insertion loss 0.9dB, is 10.9dB (=10log(10/100)+0.9) for 10% output branch, and 1.36dB (=10log(90/100)+0.9) for 90% output branch, and 3.91dB (=10log(50/100)+0.9) for 50% output branch, respectively. 1.36dB(=10log(90/100)+0.9) as the insertion loss of 2×1 coupler was calculated because 90% of input power was transmitted into next stage under normal state. The insertion loss of optical switch is given by 1dB, and the connector loss is 0.5dB for FC/PC type. The optical fiber loss(0.36dB/Km) is ignored since total optical fiber length in OPS is very short.

Generally, in the case of 1mW output power from the transmitter, the logical 'High' corresponds to -0dBm power level and the logical 'Low' corresponds to -10dBm when the ER(Extinction Ratio) is given to 10dB. Therefore, the averaged optical output power in the time domain becomes -5dBm (=(0dBm -10dBm)/2) because of the same probability of logical state. Therefore, when the logical 'High' correspond to 1mW power level, the averaged optical output power of the transmitter with the speed of 155.52Mbps(STM-1 level) becomes -5.0dBm. The receiver sensitivity of commercial optical receiver module which is capable of detecting 20~650Mbps, is about -38dBm. The total power loss values calculated for each path based on the above given values are P_{T1}=17.97(dB), P_{T2}=10.17(dB), and P_{T3}=11.9(dB). From the results, the proposed OPS unit was well satisfied with the system power penalty of eq. (4).

2. Maximum Distance between ONUs and ONU Number to be bypassed.

Using the -5dBm optical output power of transmitter, the number of ONU which can be bypassed at once, were also calculated based on the below path 4.

- PATH 4 : optical transmitter 1 → optical splitter 2 → optical switch 2 → optical coupler 3 → bypassed ONU×N → optical splitter 1 → optical receiver 1 of (N+1)th ONU.

$$P_{T4}=n_1L_1+n_2L_2+n_sL_s+n_{cn}L_{cn}+l_fL_f \text{ (dB)} \quad (5)$$

The results are shown in Table 1 and Fig. 6. Table 1 summarizes the maximum distance between ONUs, depending on the combinations of splitter ratio. If the ratio of both splitters is 90/10%, the maxium distance is about 11.32Km. By the way, in case of 50/50% splitter ratio, the distance is about 0.7Km. Fig. 6 shows the number of ONU which can be bypassed, versus the variation of distance between ONUs. Two ONU can be bypassed in the case of splitter ratio, 90/10% and the distance between ONUs, 5.1Km.

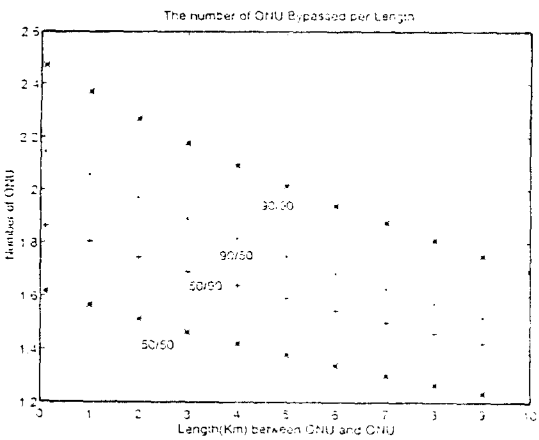

Figure 6. The maximum number of ONUs which can be bypassed with the initial optical power of transmitter (average optical power : -5dBm)

Ⅳ. OPS Fabrication and Performance Test

The resultant hybrid OPS unit was tested by coupling with 1227-type ASTROTEC(AT&T) optical transmitter module which includes an InGaAsP laser diode with wavelength, 1310nm. As the optical power detector in ONU, 1310-type ASTROTEC(AT&T) receiver operated in the range from 1310nm to 1550nm was used, and its dynamic range is 20-650Mbps. SF4-E-1300P(CANSTAR) optical fiber couplers with the low insertion loss and stable characteristics for temperature change were used. SW11A1-10FP optical switch is capable of switching optically(1×1) according to the applied electrical signal, and its backward reflection ratio is below -55dB.[9]

The monitoring circuit checks the situations of current ONU, and control signal are sent to switches for each situation. The out of order state and restoration to the normal state are distinguished by the monitoring circuit, and the current ONU state is displayed by LED. Fig. 7 shows the block diagram of the monitoring circuit. When the

Table 1. The maximum distance between ONUs. (average optical power : -5dBm)

	Splitter 1 : 90% Splitter 2 : 90%	Splitter 1 : 90% Splitter 2 : 50%	Splitter 1 : 50% Splitter 2 : 90%	Splitter 1 : 50% Splitter 2 : 50%
Maximum distance between ONUs	11.32 Km	7.78 Km	4.24 Km	0.70 Km

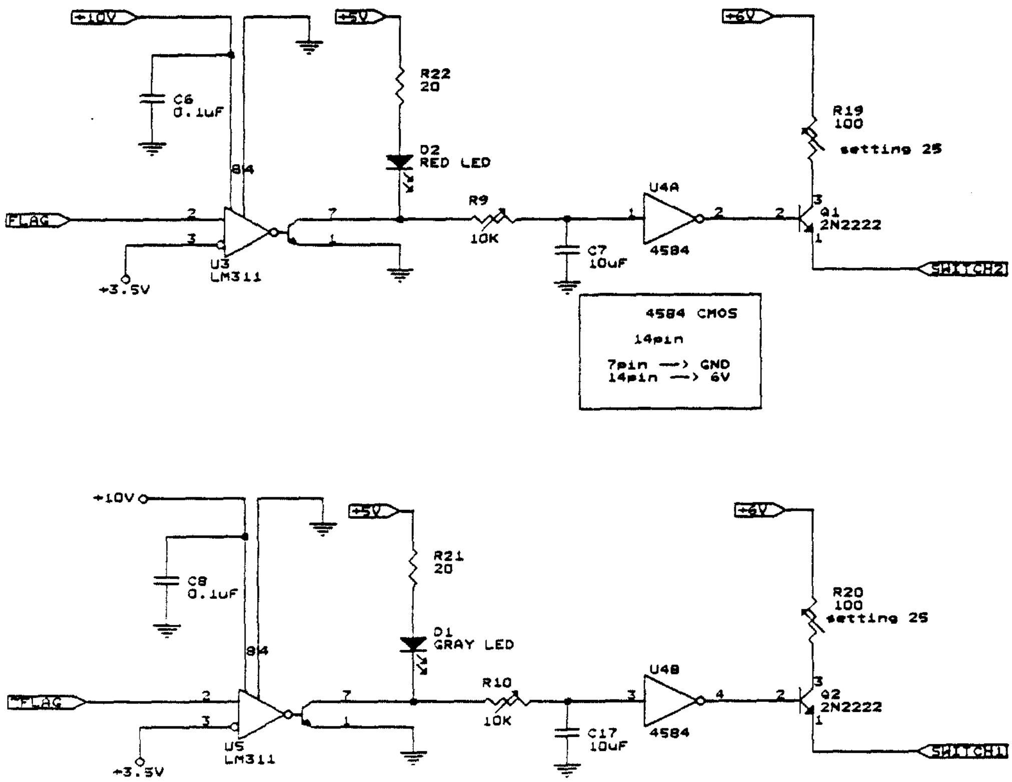

Figure 7. The block diagram for monitoring circuit.

breakdown of current ONU happens, the output of flag signal from receiver 2 is 3.8V, and 3.0V in the reverse case. The flag signal is compared with the comparator reference voltage(3.5V), and then control signals are sent to the switches for each case.

Fig. 8 show experimental results under the setting of the optimized delay time. The clean switching transition with no data loss and no data collision under the transmission speed of STM-1 level (in the case of breakdown of current ONU) was observed as shown in the upper trace of Fig 8. The lower trace also shows the good switching transition for the restoration to the normal state of current ONU. We set the delay time to 0.5ms, which is same as the optical transition time of the optical switch module used for our experiment. The best operation of the OPS could be conformed experimentally.

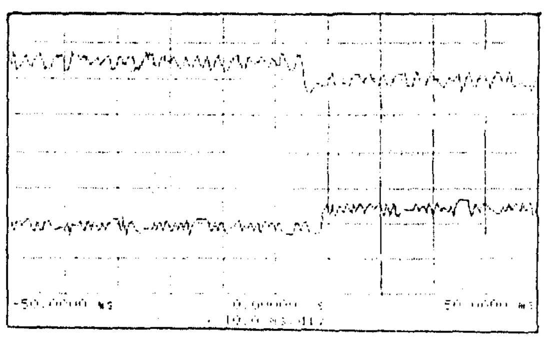

Figure 8. The switching performance test in the case of current ONU breakdown (the upper trace) and restoration (the lower trace)

V. Conclusion

In this study, we constructed the hybrid-typed OPS unit using passive optical fiber devices. Through the performance test with STM-1 level optical data, we have obtained the most optimal protection with the least data loss or collision during the switching transition. The maximum number of ONU which can be bypassed and the maximum distance between ONUs under the actual system transition were calculated through the system power budget simulation. It is believed that the proposed OPS can be applied to an actual CPN, and be expected to play a major role for the improvement of subscriber network reliability.

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