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Improved performance analysis of Gigabit passive optical networks

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ABSTRACT

Gigabit passive optical networks (GPON) provide a capacity boosts in both the total bandwidth and bandwidth efficiency through the use of larger variable-length packets in Passive Optical Networks technology. In this paper, we have described a purely-passive GPON compatible reach extender using distributed Raman amplification and reported the improved investigation through implementation of a square root module by a distance of 60 km at data rate of 2.5 Gbps. An efficient improvement in Q factor is achieved with square root module, which further helps in increasing the length of GPON.

1. Introduction

Passive optical networks (PONs) are now being deployed in large numbers worldwide and will play an increasingly important role in future broadband access networks. PON was invented at British Telecom in the late 1980s. The original concept was to use time division multiplexing to divide the available link bandwidth over many subscribers. The fiber network between the central office equipment and the customer's equipment would be entirely passive. This was strongly motivated at the time by the relatively high cost of lasers (costing well over US$1000 at that time) and the low rate of users bandwidth (telephony was the main application). For this reason, a great amount of research was initiated to study PONs. PONs has been seen as an important part of many Fibers to the Home (FTTH) strategies. Primarily, PONs is attractive because they economize on fibers leading from the central office out to serve the communities and reduce the number of optoelectronics at the central office, bringing direct and indirect savings. However, a long time has elapsed since the original development of PON until the large deployments happening today. There are both technical and economic reasons for this. Passive optical networks are economically attractive because several users can share common resources. Typically, upto 64 users can share a PON port on an OLT. The per-user cost of the OLT decreases as more users share the same port. Depending upon optical splitter placement, various portions of outside plant (OSP) resources like fiber material and splicing costs may also be shared among multiple users. By increasing the sharing of OSP resources, certain splitter architectures decrease the OSP per-user cost. However, these architectures limit the sharing efficiency of OLT resources resulting in a net increase in total per-user cost [1–6]. Presently there are three major PON technologies under consideration as the basis for FTTH deployments: Broadband PON (BPON), GE-PON and Gigabit PON (GPON) [7]. This paper focus on Gigabit Passive Optical Network (GPON). It is defined by ITU-T recommendation series G.984.1 through G.984.4. GPON has enhanced capability comparing with APON and BPON. G.984 standard series define general characteristics of GPON (G.984.1) as well as physical layer specification (G.984.2), transmission layer specification (G.984.3) and ONU (optical network unit) management and control specification (G.984.4). GPON can transport not only Ethernet, but ATM and TDM traffic by using GPON encapsulating method (GEM) [8]. Raman amplification in the transmission fiber is one such technique that could improve the PON loss budget with the addition of suitable pump lasers coupled to the fiber at the central office (OLT). There has been a recent report on such an idea [9] but this system demonstration deviated from the GPON standards in some respects. Here we have proposed to use a square root transfer function module similar as reported in [10]. The SQRT transfer function module has been placed after the photodiode which compensates its square law characteristic for improving the performance of linear equalizer [11].

Here [12] a purely passive GPON compatible reach extender using distributed Raman amplification has been described. Operation over 60 km of all wave fibers at 2.5 Gbps is demonstrated with a total loss budget of 43 dB at 1310 nm. The system performance of such purely passive GPON extender investigated in Ref. [13]. The system transmission limitation of upstream signal due to Raman ASE noises discussed and the non-linear impairment on downstream signal due to high launch power into feeder fiber examined. Here [14] experimental demonstration of GPON reach extension

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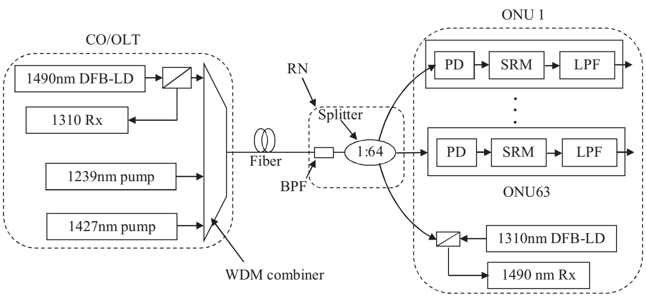

Fig. 1. Simulative set up of GPON.

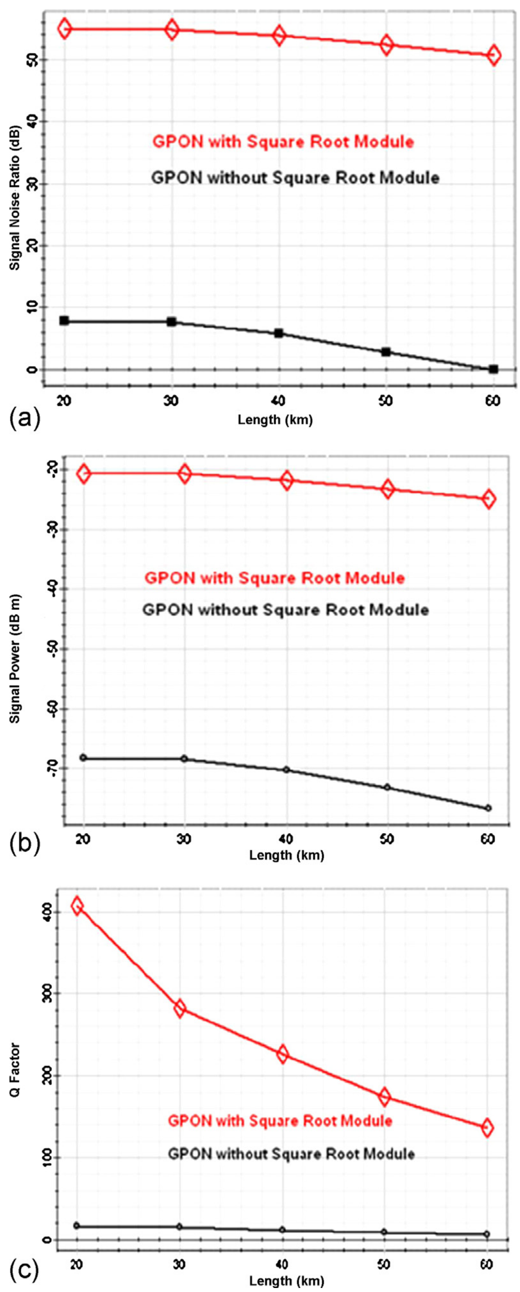

Fig. 2. (a) Evaluation of SNR versus length with and without SR module. (b) Evaluation of signal power versus length with and without SR module. (c) Evaluation of Q factors versus length with and without SR module.

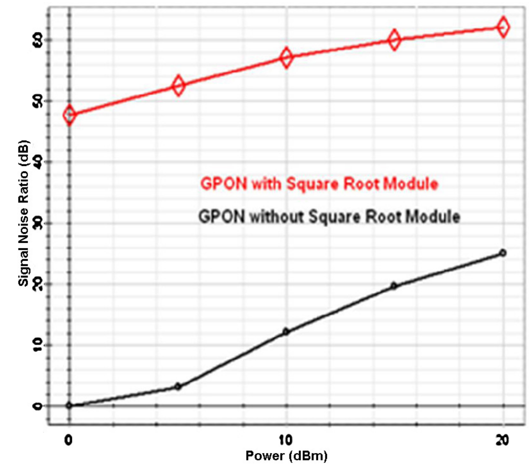

Fig. 3. Evaluation of SNR versus Tx power with and without SR module.

to 50 km with a 1:64 PON split using Raman amplification of the upstream signal with wavelength stabilized pump lasers discussed. In this paper, we have presented the improved simulative investigation of GPON at high transmission rate of 2.50 Gbps over a spacing distance of 60 km using square root module. The paper is organized as follows: Section 2 contains the system description, Section 3 discusses the results of GPON system and Section 4 concludes this paper.

2. System description

In our proposed GPON system (Fig. 1) a central office (CO) with OLT which is connected to the remote node (RN) by 60 km of optical fiber and optical network units (ONU) at the subscriber premises. The OLT consists of a DFB laser diode (LD) at 1490 nm as the transmitter for the downstream (DS) signal, 1310 nm APD receiver, a WDM combiner and two Raman pumps at 1239 nm and 1427 nm, which provide optical pumping for distributed Raman amplification of upstream (US) and DS signals, respectively. The RN uses only passive optical components: the optical splitter and a band pass filter (BPF). The BPF is used to filter out the residual pump light for 1490 nm receivers at the ONUs. The ONU uses a DFB LD operating 1310 nm transmit US signals. In receiver portion at ONU, a square root module Mat lab code interface with OPTI-SYSTEM^{TM} simulator after photo detector as shown in Fig. 1. The 1239 nm pump light, providing counter propagating Raman gain for the 1310 nm US signal is generated in a cascaded Raman resonator (CRR) [15]. Laser diodes at 915 nm are used to pump a Yb doped cladding-pumped fiber laser, whose output at 1100 nm is input to the CRR which consists of Raman fiber and a cascaded grating set to shift the output wavelength up to 1239 nm. The co-propagating pump providing gain for the 1490 nm DS signal consists of polarization multiplexed 1427 nm LDs with RIN <150 dB/Hz. A pump near 1400 nm would provide the maximum Raman gain efficiency for a 1490 nm signal. However the US 1310 nm signal would be significantly depleted in this case. A design trade-off was made by moving the Raman pump for the DS signal to 1427 nm to minimize depletion at 1310 nm whilst providing enough gain at 1490 nm.

3. Results and discussion

In this paper, GPON system is designed with the help of OPTI-SYSTEM^{TM} simulator consisting transmission length 60 km, wavelength 1490 nm, transmitter power 3 dBm, dispersion 0 ps/nm/km. A square root module (SR module) is applied in GPON