# Novel methods for the simulation of impairments in optical network

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The practical and effective methods to implement the impairments in optical network are put forward and applied in testing the equipment reliability and transmission quality under the condition of bit errors. The results show that the proposed methods are effective in equipment reliability testing.

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The physical impairments of optical network (such as amplification of spontaneons emission (ASE) noise, polarization mode dispersion (PMD), crosstalk, nonlinear effects, etc.), which are caused by optical components and fibers, can accumulate along the light path. Those impairments degrade optical signal quality in long distance transmission. When the impairment accumulation comes to a serious degree, the bit error rate (BER) would be too high to be acceptable in the destination receiver[1].

In Refs. [1–5], ways to minimize the optical physical impairment problems by using control layer routing protocols (for instance: GMPLS) in wavelength division multiplexing (WDM) network are separately introduced. While this letter is focused on the simulation tool and the methods for generating physical optical impairments to test. Under the condition of different BERs of interface, whether serious problems such as upper layer software errors, excessive CPU usage, out of memory, abnormal reset of equipment, and power down will occur.

In order to test the reliability of equipments used in optical networks, the physical simulator which can implement the quantificational impairments should be designed. Moreover, the designed impairments simulator should have three functions. Function 1 is to generate bit errors and control the BER while exploring the problems may caused by BER at physical layer. Function 2 is to implement the exception insertion (packet loss, jittering, delay, etc.) at data link layer and network layer. Function 3 is to offer the open operating management interface, which can be realized as COM or NET port (Telnet,Web accessing). The interference interface of this simulator supports Ethernet (LAN/WAN), POS, FC, SATA, SAS and copper E1/T1, SA, RS232, and XDSL.

Based on the desired functions of the impairment simulator above, we proposed two ways (contact mode and coupling mode) to implement impairments. The diagrams of two impairment simulators are shown in Fig. 1. Figure 1(a) shows the working principle of contact mode, which directly connects the impairment simulator between two network devices. The core module of the simulator is high-speed signal switch. Through adjusting

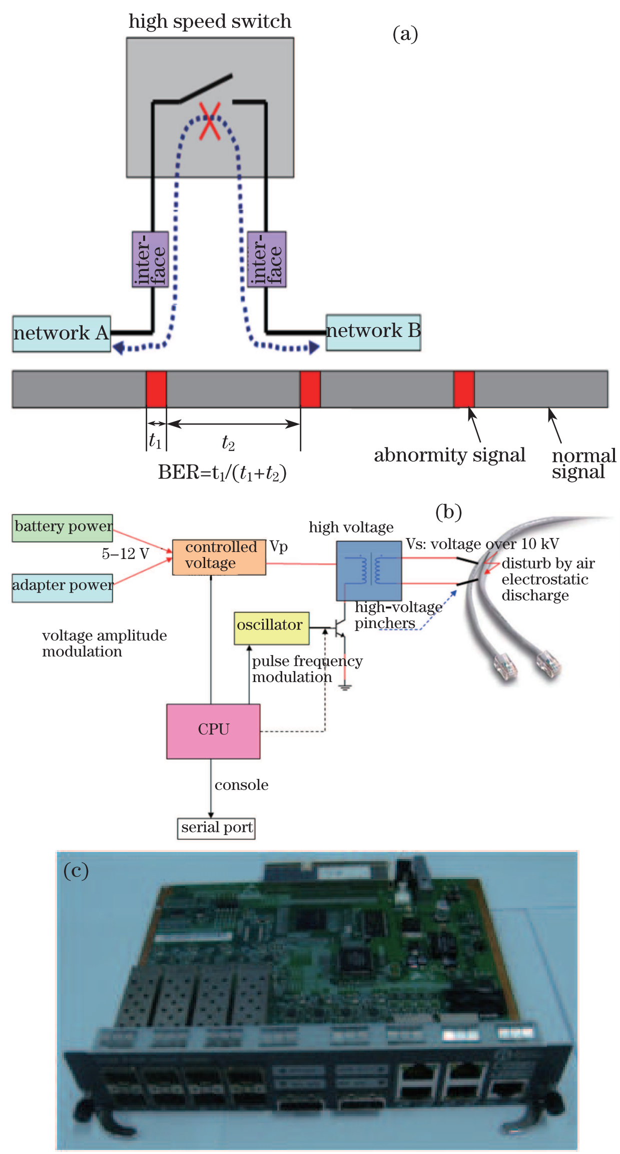


Fig. 1. (a) Contact and (b) coupling modes; (c) designed board for contact mode.

 

the on-off frequency of the switches, controllable BER can be created. Figure 1(b) shows the principle of coupling mode, which uses the discharge of strong electromagnetic field to interfere data signals and create BER. In the first mode, BER can be controlled accurately. In the second mode, there may be a damage to components and the impairment ratio is out of control. In a word, both these two modes can be used not only in optical fiber but also in copper wire.

Figure 1(c) shows the practicality of the optical physical impairments tool. The tool contains high-speed interfaces (SFP\S\SFP+\SAS), low-speed interfaces (E1\T1\SA\UART\xDSL), CPLD (interference control module), and human-machine interaction module (serial port available and Ethernet management port reserved). The entire interference interfaces separately provide the signal interference and the indicator of interference status on both transmitting and receiving path. The high and low speed switches implement the on-off switching on data path to generate the bit errors. In addition, for xDSL signals, since the high voltage feed and ringing signal exist, the blocking circuit and TVS protection circuit are designed to prevent the damage of high voltage to equipment. E1\T1 interfaces allow upper error interference interface of the uplink CPLD.

Several experiments are conducted to verify the validity of the simulation tools in both contact and coupling mode respectively.

In experiment 1, a commercial packet forwarding tester is used to implement layer 2 (Ethernet) data forwarding. It can verify the accuracy and validity of impairment simulator directly. The detailed testing configuration is shown in Fig. 2(a), an interfered link of Giga Ethernet is set in the laboratory. Commercial tester (ex. SmartBits or Tesgine in Fig. 2(a)) is connected to the interfaces of our tools and set in the loopback mode (loopback test). When interference start, the test results can be got through the comparison of packets transmitted and received. Test results are shown in Fig. 3(a). The pink part indicates the period with bit error insertion, while the green part indiactes the normal period. The three yellow lines reveal the Tx line usage, Rx line usage, and Rx HEC error, respectively. In the bit error insertion period, by comparing Tx/Rx line usage, the bit error insertion is proved to be effective. According to the steady slope of the Rx HEC error line, the BER is proved to be controllable. Also the results are consistent in separate steady period (green parts). Therefore we can make a conclusion that the bit-error injection is achieved by the impairment simulator and BER is controllable.

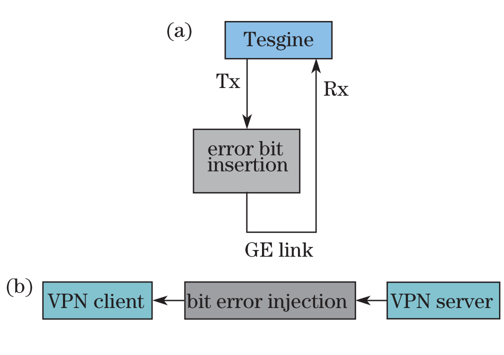


Fig. 2. Test configuration for experiments (a) 1 and (b) 2.

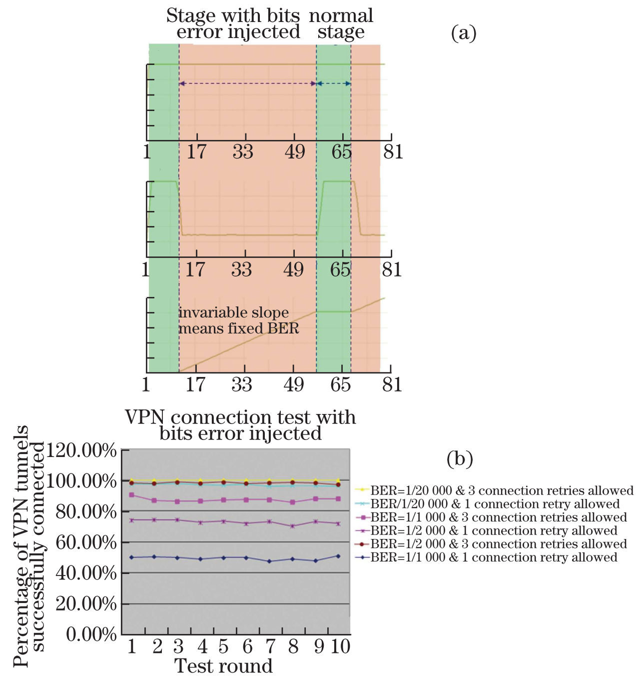


Fig. 3. (Color online) Test results for experiments (a) 1 and (b) 2.

Experiment 2 is the practical test of applying the simulation tools to a VPN network (VPN tunnel connection test). The detailed configuration is in Fig. 2(b), from which we can see the bit errors are injected to the path between VPN client and server. Test results are shown in Fig. 3(b), the bigger BER leads to the lower probabilities of successful concurrent VPN connections. With the comparison of the effect to the successful connection rate in condition of different BERs and different retries, we can conclude that: a) the successful connection rate of the VPN channel can be controlled through adjusting the BER; b) our tool can be directly applied in optical physical impairment test; c) the impairments injected by our tools are consistent.

Experiment 3 adopts the coupling mode in Fig. 1(b) to implement the impairment. In this experiment a similar electronic ignition switch with a voltage up to over 10 kV and a frequency up to over 300 Hz is applied to generate a strong electromagnetic interference. The result of the experiment 3 shows that thousands of inaccurate packets may be generated in every second. This method can be applied to every type of electric port without any change to the existing network topology. Although beside the inaccuracy of error-bit control, this method also will cause some damages to the network components.

In conclusion, we design two modes to implement impairment and apply them to the practical test system. Accurately control of BER is successfully implemented by using the contact mode for 10 G and below optical interfaces. While the coupling disturb way is inaccurate in error-bit control, it can disturb different electric interfaces. These two methods can be effectively applied in all kinds of reliability test for the network equipment with a core of impairment-aware.

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