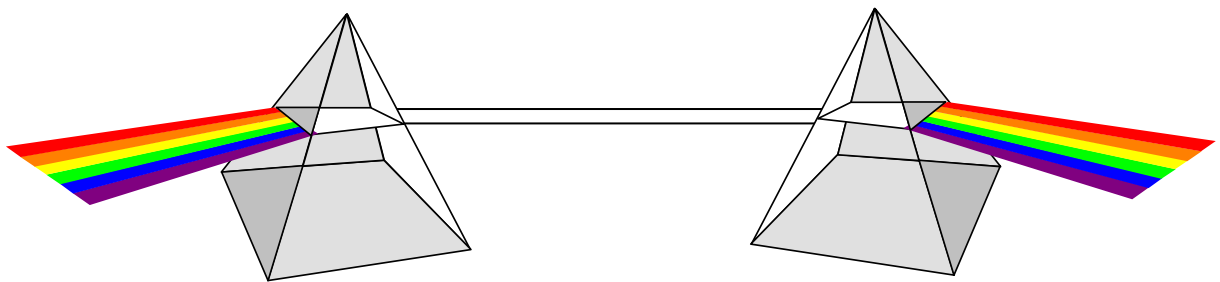


Simulation of Optical Communication Systems

Link Optimization



IMPRESSUM

© 2006 by
Wired Communications Group
Institute for Communications Engineering (LNT)
Theresienstraße 90
D-80333 München
Germany
Phone: +49 89 23472

Contents

Optimization of Optical Communication Systems..... 4

Dispersion Map 4

Recirculating Loop Experiment..... 5

Optimization of Optical Communication Systems

The several linear and nonlinear effects in the fiber influence the signal propagation of single or multiple WDM-channels of an optical transmission system. The increase of the signal power, for example, increases the optical signal-to-noise ratio (OSNR), but it also degrades the system performance due to self-phase modulation (SPM). Another example is the increase of the four-wave-mixing (FWM) efficiency as the dispersion parameter decreases. The interplay between SPM and group-velocity dispersion (GVD), explained in the Experiment 4 in terms of frequency chirp, suggests that part of the accumulated dispersion can be compensated by SPM. When all these effects act together, the optimum range of system parameters can only be determined by numerical simulations because an analytical solution is too complicated to be derived.

Therefore, the optimization process of an optical link requires first the identification of all parameters that can be varied. In order to reduce the degrees of freedom of the system, some of them should be constant. Therefore, only single-channel long-distance communication links will be analyzed in this experiment. The modulation scheme is On-Off keying (OOK) using either return-to-zero (RZ-OOK) or non-return-to-zero (NRZ-OOK) pulses. The channel consists of a cascade of identically equipped sections, as shown in Figure 1.

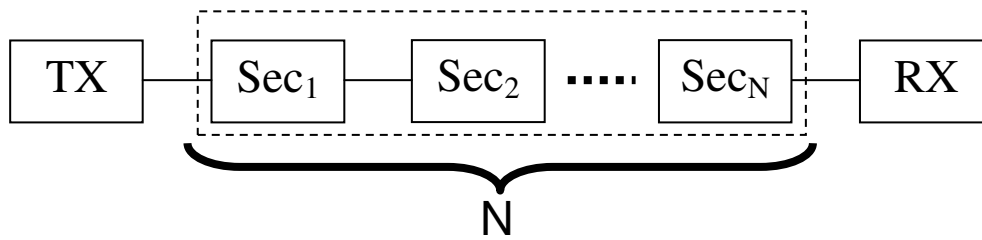


Figure 1 – System configuration

Dispersion Map

The optical fiber is a nonlinear dispersive medium. The dispersion can be compensated using dispersion-compensating fibers (DCF). Because of SPM, however, perfect dispersion compensation may not result in optimum system performance. As a result of the interplay between SPM and GVD, the actual location and compensation ratio of the DCF strongly affects transmission performance, as shown in Figure 2. Thus, an optimal dispersion map must be found for each system configuration and power regime.

Each section is composed of one 80km standard single mode fiber (SSMF), dispersion compensating fibers and optical amplifiers. Based on the dispersion compensation scheme, three types of sections are identified, i.e. pre-, post- and hybrid compensation schemes.

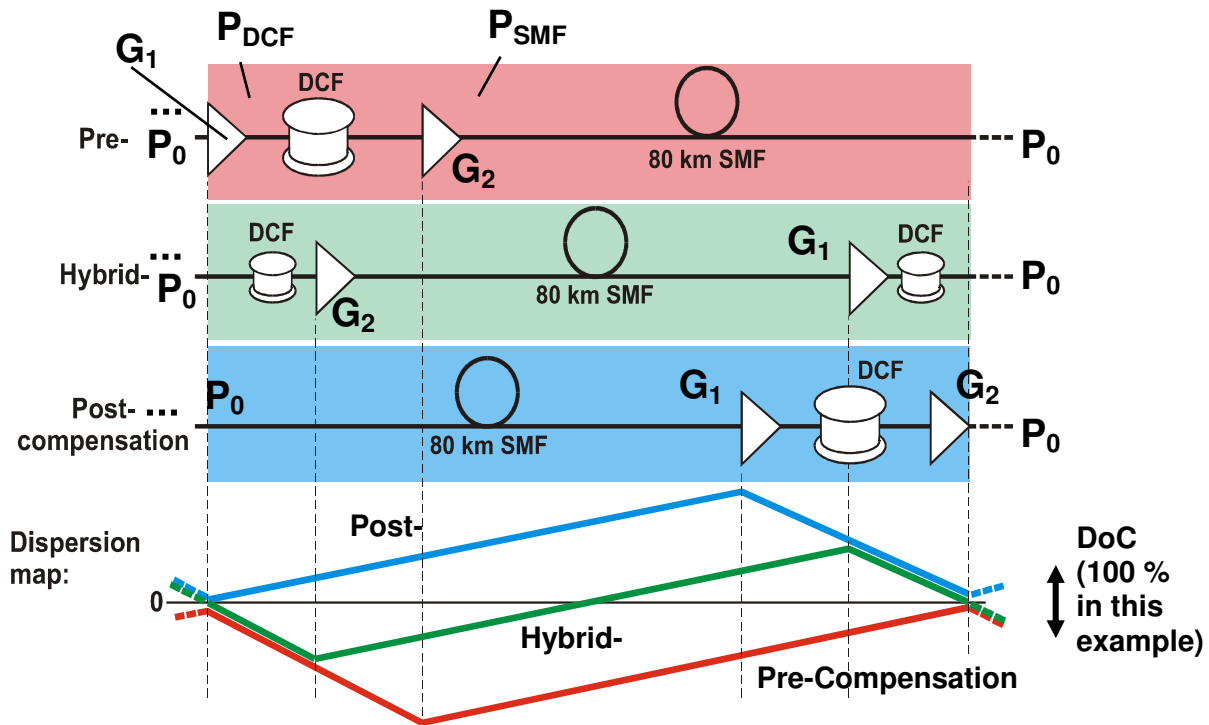


Figure 2 – Dispersion map for one section

Exercise 1: Calculate the amplifier gains G_1 and G_2 as a function of the input powers P_{SSMF} and P_{DCF} , attenuation and length of the SSMF and DCF fibers for 100% dispersion compensation. (Use a separate sheet of paper)

Exercise 2: Calculate the noise power accumulated for each dispersion-compensating scheme after N_s sections as a function of N_s , P_{SSMF} , P_{DCF} , P_{n1} and P_{n2} . (Use a separate sheet of paper)

Exercise 3: Show that the optical SNR is the same for the three dispersion-compensating schemes after N_s sections. The optical SNR is defined here as $OSNR = P_0/P_{ASE}$, where P_{ASE} is the accumulated noise power for each dispersion compensating scheme. Note in Figure 2 that P_0 is different for each case. (Use a separate sheet of paper)

Since the three dispersion-compensating schemes have the same optical SNR at the end of the transmission path, they should give the same performance. However, since the optical fiber is a nonlinear medium, each dispersion-compensating scheme produces different output signals. Therefore, the optimization procedure consists of determining the system configuration which gives the best performance.

Recirculating Loop Experiment

A loop experiment attempts to emulate the transmission performance of a long system by recirculating an optical data signal through a modest length amplifier chain ranging from tens to hundreds of kilometers. The loop transmission experiment (Figure 3) contains elements typically found in conventional experiments, such as an optical transmitter, a chain of amplified fiber sections, and diagnostic equipment such as a bit error ratio test set (BERTS). In the loop experiment, optical switching is added to allow data to flow into the loop (the load state: TX SW on; Loop SW off) or to allow data to circulate (the loop state: TX SW off; Loop SW on).

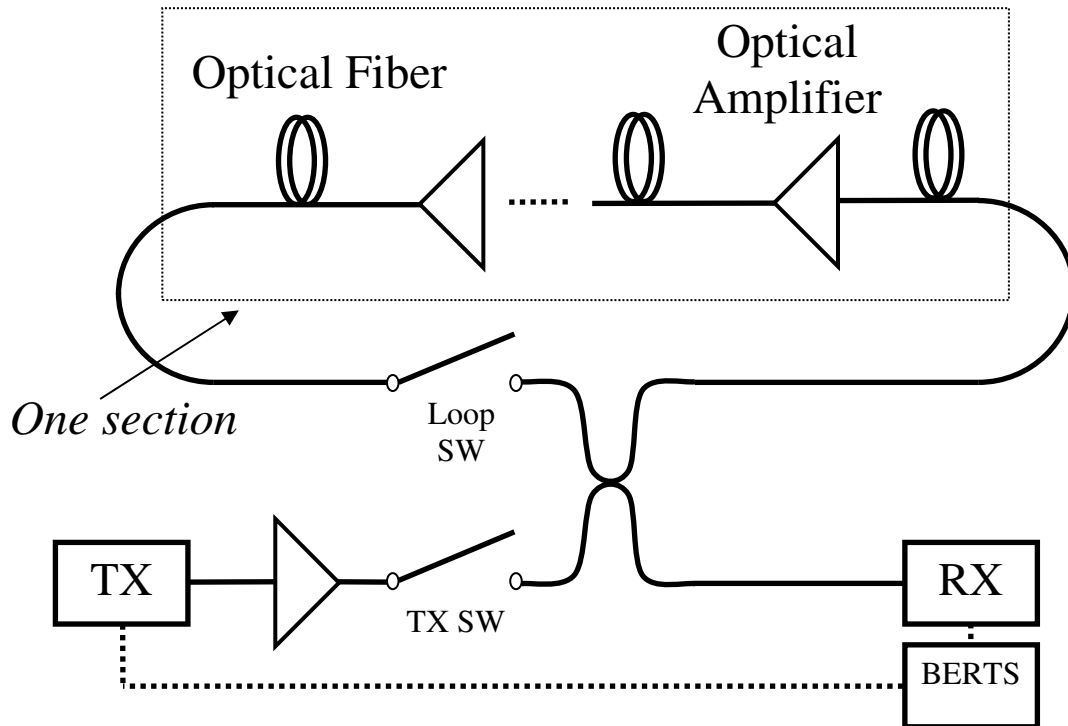


Figure 3 – Recirculating loop experiment

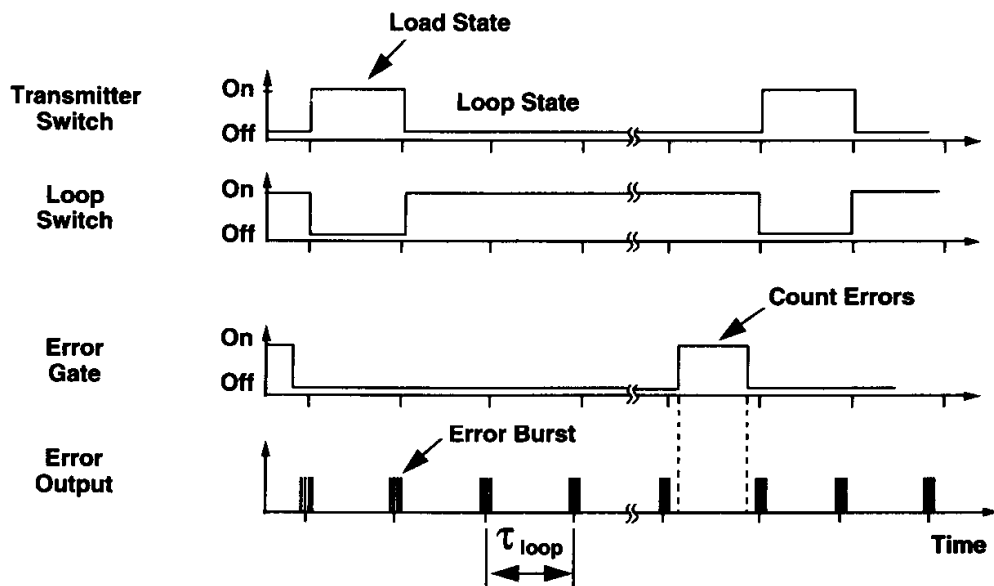


Figure 4 – Loop timing diagram

The basic time unit for the experiment is the round trip time of the closed loop τ_{loop} , which is $4.89 \mu\text{s}/\text{km}$ of fiber. With reference to the timing diagram of Figure 4, the experiment starts with the transmitter switch on (or transmitting light) and the loop switch off (or blocking light). The two switches are held in this load condition for at least one loop time to fill the loop with the optical data signal. Once the loop is loaded with data, the switches change state to the loop configuration, and the data is allowed to circulate around the loop for some specified number of revolutions. A portion of the data signal is coupled to the receiver for analysis. The data signal is received and re-timed by the regenerator and compared to the transmitted signal in the BERTS for error detection. The error signal from the BERTS is

combined with the Error Gate in a logic AND gate so that only the errors in the last circulation are counted. The measurement continues, switching between the load and the loop states so that errors can be accumulated over long intervals of time. The BER is calculated as the number of errors detected in the error gate period divided by the total number of bits transmitted during the observation period.

Exercise 4: Calculate the round trip time if the section in Figure 3 is composed of 80km SSMF and 10km DCF.

The recirculating loop can also be used in simulation of optical communication systems. The configuration is much simpler because there is no need to synchronize the whole system. Therefore, only the one section has to be implemented and placed into the loop.