Application Note AN2012-02

Fiber-Optic Amplifiers

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INTRODUCTION

SEL manufactures many devices that communicate using fiber-optic technology. The optical distances these devices operate over vary based on the type of optical components used. SEL manufactures products that operate from a few hundred meters to greater than 100 kilometers.

This application note is intended to address systems with fiber-optic paths greater than 100 kilometers and fiber-optic products operating in the 1550-nanometer light range.

PROBLEM

Occasionally, fiber-optic cable installations span distances greater than the maximum range specified for the SEL product to be applied. Additionally, the cable route may not allow for the use of repeater sites, or the best location for a repeater site may be greater than the reach of the SEL product to be applied.

SEL SOLUTION

When applying an SEL fiber-optic product in an application with a fiber span greater than the maximum cable length listed in the product specification, the addition of an optical amplifier is one possible solution. SEL recommends the use of an erbium-doped fiber amplifier (EDFA) for these applications. This device amplifies light in the 1529- to 1562-nanometer range. An EDFA is not data-rate dependent and can be applied to the following SEL products with 1550-nanometer fiber options as applicable:

- SEL-2831 Single-Mode Fiber-Optic Transceivers
- SEL-311L Line Current Differential Protection and Automation System
- SEL-411L Advanced Line Differential Protection, Automation, and Control System

Fiber System Gain Calculations

SEL uses conservative figures to calculate the distances each fiber-optic product can reliably communicate over. When applying an SEL product at the stated maximum distance and beyond, always start with the system gain capabilities of the product. The following is the simple formula to calculate system gain:

System gain = TX power – RX sensitivity

The following is an example for the SEL-311L with 1550-nanometer optics:

–18 dB TX power – (–58 dB RX sensitivity) = 40 dB system gain

The system gain is the maximum level to which the transmitted signal can be attenuated as it passes through the fiber system. Figure 1 depicts the various system components that contribute attenuation in a system.

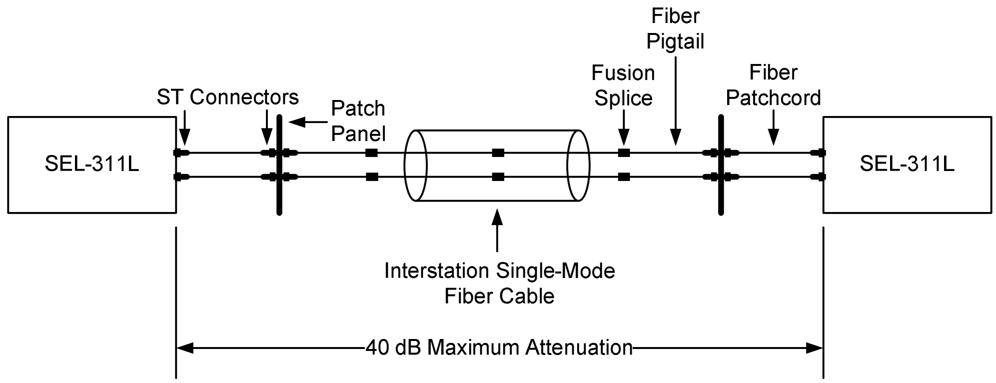

Figure 1 Fiber System Loss Budget Example

The system loss budget calculated in Table 1 demonstrates the maximum calculated fiber distance the SEL-311L can operate over. The values used are typical for low-loss fiber cable; calculations should be performed using actual cable attenuation (dB/km) figures for every system that will operate close to the specified maximum limit for the product being used. The fiber cable installation should also be measured when the installation is complete to verify the calculated versus measured attenuation performance.

Table 1 Fiber-Optic System Loss Calculation Example

Typical Attenuation Value	Loss Calculation	System Loss Budget
Cable attenuation = km • 0.22 dB/km	174 km • 0.22 dB/km	38.28 dB
Splice loss = 0.05 dB per splice, every 6 km	30 • 0.05 dB	1.5 dB
Fiber connector loss = 0.03 dB per connector	3 • 0.03 dB	0.09 dB
	Total system loss	39.87 dB

Note: System gain – total system loss = system margin. In the examples in this application note, we show very low margins. SEL recommends 3 dB of margin on any fiber system.

Application of an Erbium-Doped Fiber Amplifier

An EDFA can be used to boost the transmitted optical signal level. This amplifier can operate in several modes. This application note is specific to the booster amplifier operating mode. In this mode, the amplifier is collocated with the transmitting optical device as shown in Figure 2.

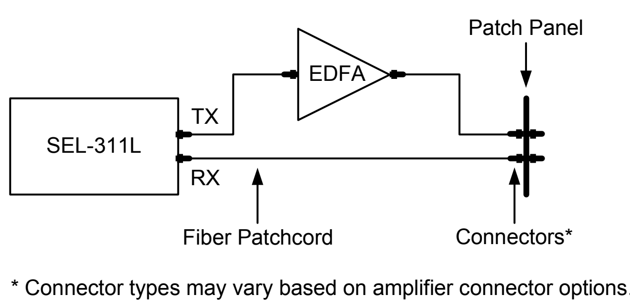

Figure 2 Application Example of a Booster Amplifier

A typical booster amplifier will add 14 dB to the transmitted optical signal. Care should be taken not to exceed the maximum input level of the amplifier (typically 0 dBm). This amplification can be added directly to the calculated gain of the system. For example, the SEL-311L system gain of 40 dB previously calculated will increase to 54 dB when an amplifier is used as shown in Figure 2. Table 2 demonstrates that with 54 dB of system gain, distances of up to 235 kilometers are achievable. Note that to achieve the 235-kilometer distance, the attenuation values of Table 2 must be achieved.

The following is an example of the system gain for the SEL-311L with 1550-nanometer optics:

–18 dB TX power – (–58 dB RX sensitivity) = 40 dB system gain

40 dB system gain + 14 dB amplifier gain = 54 dB system gain

Table 2 Fiber-Optic System Loss Calculation Example With an EDFA

Typical Attenuation Value	Loss Calculation	System Loss Budget
Cable attenuation = km • 0.22 dB/km	235 km • 0.22 dB/km	51.7 dB
Splice loss = 0.05 dB per splice, every 6 km	40 • 0.05 dB	2 dB
Fiber connector loss = 0.03 dB per connector	3 • 0.03 dB	0.09 dB
System gain with amplifier	Total	53.79 dB

The amplifier tested to date yielded a system gain of >14 dB. The information for this amplifier is: Telecom Engineering, Inc., +1.888.250.1562, model number TEOA-17-BOA-2-LCU-UTL.

Signal Dispersion at Higher Bit Rates

The amplifier example shown in Figure 2 can be applied to the SEL-311L, SEL-411L, and SEL-2831 products. These products communicate at relatively low bit rates of 64 kbps or less. The SEL ICON™ Integrated Communications Optical Network interface operates at a much higher rate of OC-48 (2.44 Gbps). At this high bit rate, an additional concern is the effect of chromatic dispersion.

Chromatic dispersion is the broadening of the signal pulse over distance. The combination of the 2.44 Gbps bit rate and the long fiber span (>100 kilometers) brings dispersion into play for this application. Due to the effect of dispersion on the 2.44 Gbps signal, booster amplifiers are not recommended for use with the ICON at the OC-48 line rate. ICON nodes used as repeaters are required to increase the reach to greater than the 100-kilometer range of the longest-reach small form-factor pluggable (SFP) transceiver.

Closing Note

This application note is intended to provide an alternate solution to repeater site equipment for long fiber cable installations. It is necessary to work with the cable provider in the selection of the right fiber for the application. The cable manufacturer should also provide guidance regarding the right fiber cable for your installation.

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