OPTICAL RETURN LOSS

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ABSTRACT

Because CATV applications are pushing the limits of fiber transmission equipment, a high quality optical fiber system is essential for the required performance. In most systems to date, the sole measure of this quality has been the attenuation of the link. However, a primary concern in CATV systems is the sensitivity of most AM fiber transmitters to reflections.

An understanding of what causes reflections in fiber systems, measures taken to minimize these, and methods to specify and test return loss for individual components and installed systems will provide the designer/installer with the tools to ensure a fiber optic system with optimum signal quality and flexibility.

OPTICAL RETURN LOSS

The benefits of transmission using fiber optics have led to great interest and aggressive plans for the design and implementation of lightwave systems for cable TV applications. In the past, conventional fiber optic systems were designed almost completely based on optical attenuation, specified as a link loss budget. However, with the recent development and installation of equipment for transmitting high-quality analog signals, potential limitations associated with the reflections of a system require attention also.

Reflections are a concern for analog transmission in particular since they can lead to significant degradation of signal quality. When light is reflected back into the laser cavity it causes interference which can create instabilities in signal output power and spectral behavior. The resultant noise will introduce power penalties and reduce the system signal-to-noise ratio.

The system designer's goal, therefore, is to minimize the source of this optical feedback and prevent its impact on laser performance. A well-planned system will maintain optimum signal quality and allow for future growth and flexibility. This goal is achieved by: a) specifying components based, in part, on their reflective qualities, and b) testing the installed system for its combined reflection or system return loss.

The Root Of All Reflections

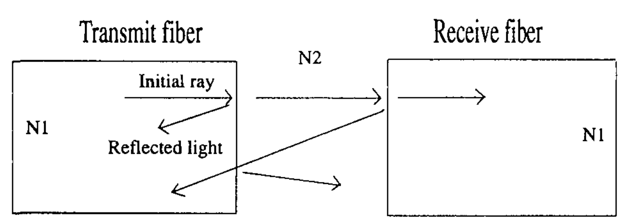
In order to optimize a system's design and selection of its components it will be helpful to understand the two basic types of reflections:

(1) **Fresnel Reflections**

These reflections occur at points in the cable where the continuity of the glass is interrupted, e.g. at connectors, mechanical splices, splitters, couplers, and other fiber optic components. These points of localized change in the light's medium are commonly seen on an optical time domain reflectometer (OTDR) as spikes.

FIGURE 1

PRINCIPAL OF REFLECTION



N1 = Index of refraction of glass

N2 = Index of refraction of air

(2) **Rayleigh Backscattering**

Backscattering is low-level reflection from the fiber itself. It is inherent to the glass structure and minimized by the design and manufacturing process of the fiber. This backscattered light is distributed over the entire length of fiber and seen as a linear trace on an OTDR.

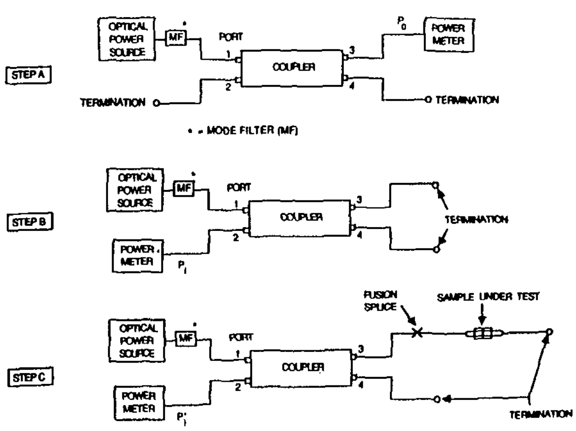
Quantifying Return Loss

In order to examine or evaluate these reflective components either individually or collectively in an installed cable system, it is necessary to quantify the amount of reflected light. This is referred to as **return loss** - simply a ratio of how much light is reflected back towards the transmitter compared to how much is transmitted out of it.

The Electronic Industries Association has recently published a Fiber Optic Test Procedure, FOTP-107, "Return Loss" that defines its test method (Figure 2). Bell Communications Research also outlines this same procedure in its Technical Reference TR-TSY-000326 on fiber optic connector specifications.

FIGURE 2

RETURN LOSS TEST SETUP



Return loss is calculated as follows:

$$\text{Return Loss} = -10 \log_{10} \frac{P_t - P_r}{P_o} + c$$

Where P_o = Optical Power Incident On Fiber

P_r = Reflected Optical Power - Reference

P_t = Reflected Optical Power - Test

And c = Constant Determined By The Characteristics Of The Test Setup

Notice that return loss is measured in dB and defined so that the smaller the amount of reflection, the larger the return loss. As a result, efforts to minimize reflections and construct a better system will actually maximize the return loss reading in dB.

Minimizing Reflections

Putting together a system with the least amount of reflection is accomplished by first evaluating and selecting individual components with small reflections. Efforts to minimize reflections are focused on the primary contributors: connectors and mechanical splices. Table 1 lists typical return loss values of components used in fiber optic cable systems.

TABLE 1	
TYPICAL OPTICAL RETURN LOSS	
• Connectors	
Conventional	15-25 dB
Physical Contact (PC Or Super PC)	30-50 dB
• Mechanical Splices	20 To >40 dB
• Fusion Splices	>50 dB
• Single-Mode Fiber	>50 dB

Actual System Return Loss:

1. Is based on combined effects of the above system components.
2. Cannot be mathematically added or calculated but is dependent on the number, magnitude and locations of the reflections.
3. Must be measured to accurately determine the combined effect of the individual components.

Development of modified polishing techniques, anti-reflection coatings, and methods of reducing the air gap between two connectors has resulted in "PC" (Physical Contact) and "super PC" connectors with higher return loss as is seen by the high upper range for connectors in Table 1.

Several mechanical splices now utilize index-matching materials, tighter tolerances, and polishing steps similar to connectors in attempts to maximize return loss.

There has also been developmental work done recently on optical isolators. An isolator attempts to mask the amount of light actually reflected back into the laser cavity. As it stands, even when isolators are used, the combination of reflections can result in noise that can significantly degrade the signal quality of the lightwave transmission system.

Determining System Return Loss

Each of the system components can be evaluated individually for its return loss performance. However, the overall system return loss is the combined effect of each Fresnel reflection, e.g. connectors, mechanical splices, and the backscatter of the fiber itself.

These reflections cannot be simply added together or calculated. Their combined effect is interdependent upon the number, magnitude, and location of all the reflections, as well as the attenuation of the fiber.

The amount of Rayleigh backscatter is based on the fiber's intrinsic scattering factor, attenuation, and response to the optical signal energy. These variables along with the effects of:

(a) Attenuation of reflections on the return trip.

(b) Multiple reflections between fiber joints, make measurement of the actual system return loss a key to predicting system performance.

Note that Rayleigh backscattering caused by the fiber plays a minor role in overall system return loss when connectors or mechanical splices are present. Therefore the system designer can maximize return loss by attempting to minimize the number and magnitude of Fresnel reflections. This is most easily and best accomplished by utilizing fusion splicing and PC connectors at fiber joints. (Reference Table 1 for a comparison of splicing and connection methods.)

System Performance

Specification of return loss for a given system is a function of the transmission equipment, indicating how much reflection it can handle while maintaining its standard of signal quality. Vendors of the equipment being used should be able to provide guidance in establishing a system specification. Measurement of system return loss would allow reliable prediction of its performance based on comparing test values with the system specification.

In addition to meeting the current return loss specification, consideration should be given to adding margin for potential future enhancements such as link extension, signal splitting, wave division multiplexing, and other enhancements requiring a minimum level of signal quality.

Summary And Recommendations

Reflections in fiber optic cable TV transmission systems can cause noise that leads to significant degradation of signal quality. Evaluation of system components and measurement of installed systems can help ensure the proper operation of the system with the required standard of signal quality. After examination of return loss - its causes, effects, and measurement - the following practical guidelines should be considered for system design and testing:

(1) Evaluation and specification of return loss of individual components prior to installation. One of the criterion for selection should be return loss.

(2) Testing the overall system return loss after installation as an acceptance test for designed system return loss specification.

(3) Considering the impact of potential future enhancements on overall system reflection in the original design and specification.

Taking these steps will lead to designing and implementing a system with optimum signal quality while maintaining flexibility for smooth growth and enhancement.

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