Fiber Optics (Volume 4) - Testing

An Online Continuing Education Course for Engineers

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Preface

This is the fourth in a series of five courses about fiber optic cable systems. The series covers fiber optics from basic light theory transmission to cables, connectors, testing, and signal transmission.

The complete series includes these five courses:

1. Fiber Optics I – Theory
2. Fiber Optics II – Cable Design
3. Fiber Optics III – Connectors
4. Fiber Optics IV – Testing
5. Fiber Optics V – Equipment

The first course, *Fiber Optics I –Theory*, is an overview of the technology of fiber optic cables including a description of the components, history, and advantages of fiber optic cables. This course also discusses the electromagnetic theory of light and describes the properties of light reflection, refraction, diffusion, and absorption.

The second course, *Fiber Optics II – Cable Design*, explains the basic construction of fiber optic cables including the types of cables, cable properties, and performance characteristics. The course reviews multimode, single mode step-index and graded index fibers, and fabrication procedures.

The third course, *Fiber Optics III - Connectors*, describes fiber optic splices, connectors, couplers and the types of connections they form in systems. It includes a discussion on the types of extrinsic and intrinsic coupling losses, fiber alignment and fiber mismatch problems, and fiber optic mechanical and fusion splices.

The fourth course, *Fiber Optics IV - Testing*, describes the optical fiber and optical connection laboratory measurements used to evaluate fiber optic components and system performance, including the near-field and far-field optical power distribution of an optical fiber. This course also reviews optical time-domain reflectometry (OTDR).

The fifth course, *Fiber Optics V - Equipment*, explains the principal properties of an optical source and fiber optic transmitters, the optical emission properties of semiconductor light-emitting diodes (LEDs) and laser diodes (LDs), and explains the operational differences between surface-emitting LEDs (SLEDs), edge-emitting LEDs (ELEDs), superluminescent diodes

(SLDs), and laser diodes.

It is not necessary to take the courses in sequence. However, for best comprehension it is suggested that the courses be taken in the order presented

Introduction

This is Volume IV of five volumes on fiber optics systems. This volume is concerned with the measurement and testing procedures used with of fiber optic cables.

This course describes the optical fiber and optical connection laboratory measurements used to evaluate fiber optic components and system performance, including the near-field and far-field optical power distribution of an optical fiber. Optical fiber launch conditions and modal effects that affect optical fiber and optical connection measurements are reviewed. The course also reviews optical time-domain reflectometry (OTDR) and how to interpret an optical time-domain reflectometer (OTDR) trace.

Fiber Optic Measurement Techniques

Fiber optic data links operate reliably if fiber optic component manufacturers and end users perform the necessary laboratory and field measurements. Manufacturers must test how component designs, material properties, and fabrication techniques affect the performance of fiber optic components. These tests can be categorized as design tests or quality control tests. Design tests are conducted during the development of a component. Design tests characterize the component's performance (optical, mechanical, and environmental) in the intended application. Once the component performance is characterized, the manufacturer generally only conducts quality control tests. Quality control tests verify that the parts produced are the same as the parts the design tests were conducted on. When manufacturers ship fiber optic components, they provide quality control data detailing the results of measurements performed during or after component fabrication.

End users (equipment manufacturers, maintenance personnel, test personnel, and so on) should measure some of these parameters upon receipt before installing the component into the fiber optic data link. These tests determine if the component has been damaged in the shipping process. In addition, end users should measure some component parameters after installing or repairing fiber optic components in the field. The values obtained can be compared to the system installation specifications. These measurements determine if the installation or repair process has

degraded component performance and will affect data link operation.

Whenever a measurement is made, it should be made using a standard measurement procedure. For most fiber optic measurements, these standard procedures are documented by the Electronics Industries Association/Telecommunications Industries Association (EIA/TIA). Each component measurement procedure is assigned a unique number given by EIA/TIA-455-X. The X is a sequential number assigned to that particular component test procedure. System level test procedures are assigned unique numbers given by EIA/TIA-526-X.

Laboratory Measurements

Providing a complete description of every laboratory measurement performed by manufacturers and end users is impossible. This section only provides descriptions of optical fiber and optical connection measurements that are important to system operation. The list of optical fiber and optical connection laboratory measurements described in this section includes the following:

- Attenuation
- Cutoff wavelength (single mode)
- Bandwidth (multimode)
- Chromatic dispersion
- Fiber geometry
- Core diameter
- Numerical aperture (multimode)
- Mode field diameter (single mode)
- Insertion loss
- Return loss and reflectance

End users routinely perform optical fiber measurements to measure fiber power loss and fiber information capacity. End users may also perform optical fiber measurements to measure fiber geometrical properties. Optical fiber power loss measurements include attenuation and cutoff wavelength. Optical fiber information capacity measurements include chromatic dispersion and bandwidth. Fiber geometrical measurements include cladding diameter, core diameter, numerical aperture, and mode field diameter. Optical connection measurements performed by end users in the laboratory include insertion loss and reflectance or return loss.

Attenuation

Attenuation is the loss of optical power as light travels along the fiber. It is a result of absorption, scattering, bending, and other loss mechanisms. Each loss mechanism contributes to the total

amount of fiber attenuation.

End users measure the total attenuation of a fiber at the operating wavelength (λ). The *total attenuation (A)* between an arbitrary point X and point Y located on the fiber is,

$$A = 10 * \log(\frac{P_x}{P_y})$$

Where,

A = Total attenuation, dB.

P_x = The power output at point X.

P_y = The power output at

Point X is assumed to be

amount of attenuation will vary with

The *attenuation coefficien*

Where,

α = Attenuation coefficien

dB/km. A = Total attenuati

L = Distance between point

Alpha (α) is a positive numbe

larger than P_y. The attenuation coefficient will also vary with changes in lambda (λ).

Cutback Method

In laboratory situations, end users perform the cutback method for measuring the total attenuation of an optical fiber. The cutback method involves comparing the optical power transmitted through a long piece of test fiber to the power present at the beginning of the fiber.

The cutback method for measuring multimode fiber attenuation is EIA/TIA-455-46. The cutback method for measuring single mode fiber attenuation is EIA/TIA-455-78. The basic measurement process is the same for both of these procedures. The test method requires that the test fiber of