



AEROSPACE RECOMMENDED PRACTICE

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(R) Guidelines for Testing and Support of Aerospace,
Fiber Optic, Inter-Connect Systems

RATIONALE

A single source document to capture current best practices, methods, test equipment, and materials that support fiber optic interconnect systems deployed in aerospace platforms.

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1. SCOPE

ARP5061A provides guidelines for optical performance testing of short haul fiber optic inter-connection systems used in aerospace vehicles. The focus of this document is to introduce the proper testing tools and establish common pre- and post-installation test methods and troubleshooting methodologies.

1.1 Applicability

This document establishes guidelines applicable to test fiber media which includes fiber optic cables, connectors (simplex, multi-pin, and ribbon), passive and active elements affecting optical power distribution through inter-connect hardware. Where there is conflict between this document and the vehicle specification or contract, the vehicle specification or contract should take precedence. Where design is such that the methods herein cannot be implemented, users will submit relevant information or modifications to existing methods to the AS-3 Committee for review.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5271	A Guideline for Application of High-Density Fiber Optic Interconnects to Aerospace Platforms
ARP5602	A Guideline for Aerospace Platform Fiber Optic Training and Awareness Education Aerospace Fiber Optics Quality Assurance Knowledge Competencies
ARP6031	Fiber Optic Cleaning
ARP6283	In-Service Fiber Optic Inspection, Evaluation and Cleaning, Best Practices, Physical Contact Termini
AS5603A	Digital Fiber Optic Link Loss Budget Methodology for Aerospace Platforms
AS5675	Characterization and Requirements for New Avionic Fiber Optic Cable Assemblies - Jumpers, End Face Geometry, Link Loss Measurement, and Inspection

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ANSI Z136.2 American National Standard for the Safe Use of Lasers

2.1.3 U.S. Government Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-PRF-28800	Performance Specification: Test Equipment for Use with Electrical and Electronic Equipment, General Specification For
MIL-PRF-29504	Termini, Fiber Optic Connector, Removable, General Specification For

2.1.4 ARINC Publications

Available from ARINC, 2551 Riva Road, Annapolis, MD 21401-7435, Tel: 410-266-4000. www.arinc.com.

ARINC 803 Fiber Optic System Design Guidelines

2.1.5 European Norm Publications

Available from Comité Européen de Normalisation (CEN): Available from Avenue Marnix 17, B-1000 Brussels, Belgium.

EN4532 Aerospace Series – Cables, Optical, Single Core 200/280 µm Fiber, 2.5 mm Outer Jacket – Technical Specification

2.1.6 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.S. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 825-1:1993 Safety of Laser Products

2.1.7 The U.S. Department of Health and Human Services

Available from The U.S. Department of Health and Human Services, 200 Independence Avenue, SW, Washington, DC 20201, Tel: 1-877-696-6775, www.hhs.gov.

USA FDA CDRH 21, Subchapter J, Class II, 1 mW maximum

2.1.8 TIA Publications

Copies are available from IHS Global Inc., Tel: 800-854-7179 (U.S. and Canada), +1-303-397-7956 (Outside U.S. and Canada), <http://global.ihs.com>.

TIA-440-B Fiber Optic Terminology

TIA-455-43 Output Near-Field Radiation Pattern Measurement of Optical Waveguide Fibers

TIA-455-47 Output Far-Field Radiation Pattern Measurement

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.S. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60793-1-45 Optical Fibers, Measurement Methods and Test Procedures, Mode Field Diameter, Method A

IEC 60793-1-45 Optical Fibers, Measurement Methods and Test Procedures, Mode Field Diameter, Method C

IEC 60794-1-2 Optical Fiber Cables, Part 1-2, Generic Specification, Basic Optical Cable Test Procedures

IEC 60825-1 Safety of Laser products – Part 1, Equipment Classification and Requirements

IEC 61300-3-5 Examination and Measurements, Wavelength Dependence of Attenuation

IEC 62627 Fiber Optic Interconnecting Devices and Passive Components – Fiber Optic Connector Cleaning Methods

2.2.2 TIA Publications

Copies are available from IHS Global Inc., Tel: 800-854-7179 (U.S. and Canada), +1-303-397-7956 (Outside U.S. and Canada), <http://global.ihs.com>.

TIA-455 Fiber Optic Test Procedures

TIA-568 Optical Fiber Cabling Components Standard

2.2.3 U.S. Government Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-STD-810 Test Method Standard

MIL-STD-1472 Human Engineering

MIL-STD-1678 Fiber Optic Cabling Systems Requirements and Measurements

MIL-PRF-49291 Optical Fiber (Metric), General Specification For

MIL-PRF-85045 Cables, Fiber Optics, (Metric), General Specification For

2.2.4 ARINC Publications

Available from ARINC, 2551 Riva Road, Annapolis, MD 21401. www.arinc.com.

ARINC 805 Fiber Optic Test Procedures

2.2.5 Other Applicable References

US NIST (National Institute of Science and Technology) absolute standard

3. TRAINING

3.1 Certification

A national or internationally recognized licensing or certification body should be responsible for the administration of the training and testing requirements. The national or internationally recognized licensing or certification body should hereafter be referred to as the certifying body. In the United States, the Electronic Technicians Association, International (ETA) is the currently recognized certifying body following industry accepted SAE International Aerospace standards per ARP5602.

3.2 Qualifications and Training Standards

The repair and maintenance of a fiber optic interconnect systems should ONLY BE PERFORMED by qualified personnel. The unique nature of fiber optic connectors, termini, installation, cleaning, inspection, and certification requires personnel that have been formally trained on the proper handling and maintenance practices. Formal fiber optic training should be performed by qualified personnel. This training should be documented, and a certification issued for both hands-on practical skills and theory. Qualification should be by a written examination(s) and a physical skills performance test.

4. SAFETY

It is the responsibility of every employer to preserve, so far as is reasonably practicable, the health, safety, and welfare of all employees. Common hazards include chemicals, optical power, fiber fragments, environmental, explosive.

Employers should ensure material safety data sheets (MSDS), first aid kits, and eye wash stations are available in all areas where fiber optic work is being conducted. Fume hoods should be utilized where applicable.

General awareness of working around aircraft and other potentially explosive environments is a consideration when utilizing any arc fusion splicers, curing ovens, ultrasonic cleaners, or other electrical or electronic devices.

In addition, all employees have a duty of care to their work colleagues. It is the responsibility of every employee, while at work, to take reasonable care for his/her own health and safety and of other persons who may be affected by his acts or omissions at work concerning:

4.1 Handling

Care should be taken when handling fibers.

Eating and drinking near fibers increases the risk of accidental ingestion of glass fibers. All eating and drinking must not be permitted. In addition, fiber fragments can adhere to skin oils, so after working with fibers, individuals must ensure their hands are thoroughly washed before touching the face or eyes.

During installation and repair, all snipped or cleaved pieces of optical glass fibers must be placed in appropriate dedicated disposal containers. Placing fibers on an adhesive tape strip can be dangerous and must not be allowed. Wherever possible, the cutting or cleaving of optical fibers should be carried out over a mat of high contrast so the fiber fragments are seen more easily. Fiber waste must never be placed in ordinary garbage for routine disposal. Cables with exposed fiber ends must be protected or positioned to preclude accidental skin puncture or eye damage. The most effective defense against fiber-related injury is common sense.

4.2 Eye Safety

Unmated connectors and fibers may transmit non-visible radiation that could be damaging to the eye; therefore, direct viewing by eye should be avoided at all costs. Do not inspect active fiber optic systems with optical magnifying scopes. Protective end caps and approved connector covers should always be kept on all unmated connectors and termini. For additional eye safety precautions, refer to ANSI Z136.2, American National Standard for the Safe Use of Lasers. Pathological risks from a range of wavelengths are listed in Table 1.

Protection to prevent fragments from entering the eye can be achieved by wearing protective eyewear. The clear lenses can stop a fiber from piercing the eyeball or minute fragments from entering the eye. Flying glass fragments are often the results of cutting and cleaving operations. Additionally, these fragments are often present when handling chemicals and cutting fiber. Figure 1 shows details of the human eye.

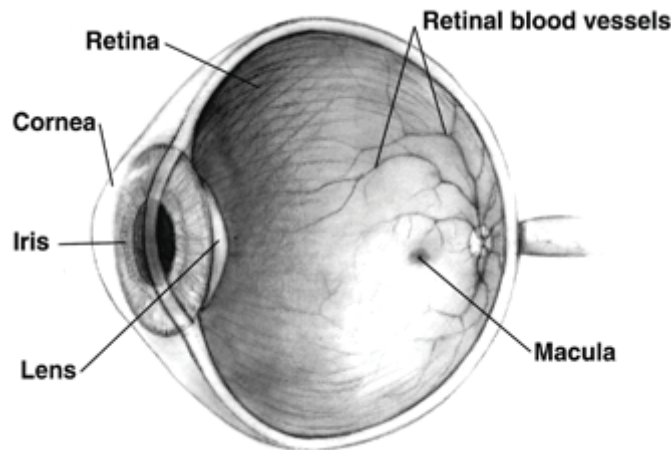


Figure 1 - Diagram of the human eye

Table 1 - Pathological risks

Wavelength range	Pathological Effect
180–315 nm (UV-B, UV-C)	photokeratitis (inflammation of the cornea, equivalent to sunburn)
315–400 nm (UV-A)	photochemical cataract (clouding of the eye lens)
400–780 nm (visible)	photochemical damage to the retina, retinal burn
780–1400 nm (near-IR)	cataract, retinal burn
1.4–3.0 μm (IR)	aqueous flare (protein in the aqueous humour), cataract, corneal burn
3.0 μm –1 mm	corneal burn

4.2.1 Optical Power Source

Although the optical power level in most installations can be relatively low, the minute dimensions of fiber cores and semiconductor sources makes it possible for intensities to attain surprisingly high values. If an optical cable is disconnected or broken and the exposed end is examined, there is a risk of eye damage. This risk can be exacerbated if a magnifier or other visual aid is used.

It should always be assumed that a system is switched on until test equipment can verify the status of optical sources. Moreover, in applications that require higher intensity optical sources, system designers must include additional safety precautions to ensure the safety of maintenance personnel.

4.2.2 Lasers and Light Emitting Diodes (LED)

Light Emitting Diodes (LED) are commonly used as fiber sources and operate at wavelengths of 850 and 1300 nm. Laser sources operate at the higher wavelengths of 1310 and 1550 nm. These wavelengths are in the infrared part of the light spectrum. Lasers differ from LEDs in that they are coherent, collimated low divergence, and have small spot sizes. The 850 and 1300 wavelengths, along with visible light are focused by the eye onto the retina. Retinal receptors are particularly sensitive to the 400 to 700 nm wavelength range, but not to wavelengths outside the range; herein lies the danger. The laser will continue to focus on the sensitive retinal tissue even though the individual is unable to perceive the intense light from the laser. At the focal point, energy density can be high enough to burn the tissue, resulting in blind spots in the individual's visual field or loss of visual acuity. This may still occur even though lasers involved with fiber use are of low power compared to other laser types.

The class of a laser depends on its operating wavelength, its output power, and whether it is pulse or continuous wave. Lasers/LEDs are classified into four general categories:

4.2.2.1 Class 1

Considered “eye-safe” to the unaided eye and that no eye damage will result even from prolonged exposure to the direct beam. As the retina more heavily absorbs shorter wavelength light, especially at wavelengths below 550 nm, the allowable maximum output power of Class 1 lasers generally increases with increasing wavelengths. As laser emissions at wavelengths greater than 1400 nm are absorbed by the cornea, no focusing onto the retina occurs and the Class 1 laser maximum output power increases dramatically.

4.2.2.2 Class 2

Those for which the aversion response will protect an individual from the output. Class 2 lasers include only those emitting visible radiation, and many fiber identifiers fall into this category.

4.2.2.3 Class 3

Possess medium power and produce radiation that can cause eye damage when viewed directly, or when a magnified reflection is viewed. A diffuse reflection is not usually a hazard. Two subcategories are defined as Class 3A and Class 3B.

4.2.2.4 Class 4

High power and not used in communication/data cable plant applications. Most lasers used with fiber communications systems are well below the energy levels that would cause skin burns, but the risk of eyesight damage is very real. The danger is highest at optical outputs where energy emits directly from the laser.

4.3 Hazardous Materials

All MSDS information should be made available, and appropriate safety and handling procedures used when working with chemicals and other hazardous materials. Unless otherwise specified, or allowed in writing by the end-user, the equipment should make no use of Lithium (Li) or Mercury (Hg) batteries, radioactive materials, asbestos, hexavalent chromium, or any other designated toxic material.

4.4 Fusion Splicing

Do not operate the unit without the safety covers in place and avoid physical contact with the fusion arc. Direct prolonged viewing of the arc is not recommended, because it is high in UV radiation which can be harmful to the eyes. Do not operate this equipment in designated hazardous areas due to the potential presence of explosive gases or fumes, unless it is qualified for such environments. If there are any doubts about the presence of explosive gases contact the appropriate safety personnel.

4.5 Visual Fault Locator (VFL)

Do not point the VFL at the eyes. Use caution when examining connectors with inspection scopes; ensure that the VFL is not connected to the fiber cable being examined. When possible, ensure that aircraft systems are de-energized or optically isolated during test or maintenance, and ensure that the VFL is authorized for use on the specific platform and all safety precautions are adhered to.

4.6 Reflectometer (OTDR - OFDR)

Use caution when examining connectors with inspection scopes; ensure that the reflectometer is not connected to the fiber cable being examined. When possible ensure that aircraft systems are de-energized or optically isolated during test or maintenance and ensure that the reflectometer is authorized for use on the specific platform and all safety precautions are adhered to.

4.7 Heat Producing Equipment

Do not touch hot surfaces or exposed heat sources during operation or after initial shutdown; severe burns may occur. Common sources of heat include: epoxy curing ovens, heat guns, and fusion splicing equipment, unless it is qualified for such environments. Keep all flammable solvents and materials away from heat sources.

4.8 Foreign Object Damage (FOD)

Fiber optic installation and maintenance may produce large quantities of debris, including packaging, wipes, fibers, and swabs which can lead to FOD. It is essential that all work areas are thoroughly policed and cleaned throughout the process.

5. DEFINITIONS

5.1 General Fiber Optic Terms

For generally accepted fiber optic terms, refer to TIA-440-B Fiber Optic Terminology.

5.2 Aerospace Fiber Optic Terms

ABSORPTION: Loss of light in a fiber caused by intrinsic impurities, resulting in conversion of optical power into heat energy.

ACCEPTANCE CONE: The cone containing incident rays that couple into bound modes of the fiber. The acceptance angle is defined as the half angle of the cone.

ADD-DROP MULTIPLEXER (ADM): A single component used to multiplex lower-speed electrical and/or optical signals into a high-speed optical channel. Supports time division multiplexing (TDM) or dense wavelength-division multiplexing (DWDM).

AEROSPACE MEASUREMENT QUALITY JUMPER (AMQJ): An AMQJ is a high-quality reference jumper. It is used to connect test equipment to the link under test. Also, see LAUNCH CABLE.

AIR-GAP TYPE CONNECTOR: A connection in which the mated pair has an air gap between the fiber end faces. The gap may range from less than one to several microns (μm). The gap can result from polishing connectors to a predetermined length, as in SMA style connectors, or from having a concave polish or undercut profile on one or both end faces of the mating fibers. Gap type connectors have a high reflection from the change in refractive index from the glass fiber to the air gap.

AMPLIFIED SPONTANEOUS EMISSION (ASE): The light emitted from the decay of the upper level of a lasing transition without stimulated emission. (Broad spectral emission and unpolarized.)

AMPLITUDE MODULATION (AM): Transmission technique in which the information is encoded in the amplitude of the carrier.

ASYNCHRONOUS TRANSFER MODE (ATM): A high-speed transmission scheme providing bandwidth on demand for multimedia (data, voice, video).

ATTENUATION: The diminution of average optical power. Attenuation results from absorption, scattering, and other radiation losses. Attenuation in general is expressed in dB without a negative sign.

ATTENUATOR: An optical device that reduces the intensity of a light beam passing through it by a controlled or predetermined amount of absorption.

AVALANCHE PHOTODIODE (APD): A photodiode that produces current through internal amplification. (Avalanche multiplication)

BACK REFLECTION: Back reflection is the part of the energy launched into the fiber, which is returned towards the source by an event along the fiber. The back reflection of a flat polished glass-air interface is known as a Fresnel reflection. Its value depends only on the index of refraction of the fiber and is roughly equal to -14 dB (for standard singlemode or multimode glass fiber). Back reflection is measured by either an Optical Return Loss Meter or by an OTDR.

BACKSCATTERING: Back scattering is the portion of the energy propagating into the fiber that returns in a generally opposite direction. In current aerospace conditions (where non-linear effects are negligible), the back scattering is generated by microscopic density fluctuations along the fiber. This effect is known as Rayleigh BackScattering (RBS). For example, the back-scattered signal from a 1-inch length of 100/140 micron multimode fiber at 850 nm wavelength is typically -60 dB. It increases linearly with the length of the fiber under consideration. RBS level can be measured by reflectometers. Changes in this level can be used to measure the loss along the fiber.

BANDWIDTH: Measure of information carrying capacity; the greater the bandwidth, the greater the information carrying capacity.

BEND LOSS: The result of macrobends (curvature of fiber) or microbends (small distortions in the fiber) producing increased attenuation by coupling light energy from the fiber core to the cladding.

BIT-ERROR-RATE (BER): The number of digital highs on a transmission link that are interpreted as lows, and vice versa, divided by the total number of bits received. (BER should be better than 1×10^{-9} in properly operating systems.)

BOUND MODES: In a multimode fiber, the power in bound modes is predominately contained in the core of the fiber.

BUFFER: First and primary layer of material that covers and protects a fiber. Also known as “coating” (e.g., primary coating). Also, see COATING.

BUILT-IN-TEST (BIT): Capability of an item of equipment to have self-diagnostics, usually at power up.

CENTRAL WAVELENGTH: Wavelength of a source's peak power.

CHIRP: A change in the characteristic optical frequency of a device as a function of time (modulated diode laser) or position (chirped fiber Bragg grating).

CLADDING: Dielectric material surrounding an optical fiber core that has a lower refractive index than that of the fiber core. The low/high index boundary enables retention of light in the fiber by total internal reflection.

CLADDING BOUNDARY: Consisting of the inner and outer limits of the layer directly surrounding the core.

CLADDING LIGHT: Light propagating in the cladding.

CLADDING MODES: A mode in which the electromagnetic field is confined in the cladding and the core by virtue of there being an even lower refractive index medium (coating) surrounding the cladding.

CLEAVE: The process of breaking a fiber such that it leaves a clean end face on the fiber with minimum angular distortion. Cleaving is done by scoring the glass with an edge tool or a cleaving tool.

COATING: Layer of material that covers and protects a fiber (no optical function). Can also be defined as buffer (e.g., primary buffer). Also, see BUFFER.

COHERENCE: A phenomenon whereby the phases of the photons (or constituent wave trains) of a light beam maintain a definite relationship with each other. A narrow line-width laser is said to exhibit a high degree of coherence.

CONNECTOR: Hardware installed on cable ends to connect cables to a device or another cable and disconnect whenever desired. (See INTERCONNECT.)

CONTINUOUS WAVE (CW): Constant output from an optical source that is active but not modulated by a signal (DC).

CORE: The central region of an optical fiber with higher refractive index than that of the cladding, and within which most of the optical power is transmitted.

CORE CENTER: For a cross section of an optical fiber, it is the center of that circle which best fits the outermost limit of the core area.

CORE DIAMETER: The diameter of the circle defining the boundary between the core and the cladding.

CUTOFF WAVELENGTH: The shortest wavelength for which an optical fiber can only support the propagation of a single transverse mode.

dB: Decibel. Standard logarithmic unit measuring the ratio of two quantities. In fiber optics, the ratio between two optical powers represents loss or gain. Relative power [dB] $\equiv 10 \log (P_2/P_1)$ (see Appendix A.1).

DEADZONE – OTDR: The distance from an event, such as a reflection from a connector, over which the OTDR signal is saturated and the OTDR is not able to make measurements.

DISTANCE ACCURACY: The precision of a length measurement, as made with a reflectometer, using the value of the effective group index of the fiber.

EFFECTIVE GROUP INDEX: The effective group index of a fiber is the ratio of the pulse propagation speed in vacuum to that in the fiber. The value for glass fiber is approximately 1.5.

ENCIRCLED FLUX: A radial integration of the power distribution in the fiber, commencing from zero at the core center to unity at the core boundary.

EQUILIBRIUM MODE DISTRIBUTION: The condition in a multimode optical fiber in which relative power distribution among the bound modes is independent of length.

EVENT: An abrupt discontinuity or index change in the fiber, such as a connector, a mechanical splice, a star coupler, a break, etc. An Event generates loss in the transmission and back reflection. Its characteristics can be measured by a reflectometer. For example, a cleaved fiber end or a flat polished open connector back reflects typically 4% (or -14 dB) of the incident energy. A break in a 100/140-micron multimode fiber back-reflects from -30 to -14 dB.

FAR FIELD REGION: The region at some distance from a source or aperture where the radiation pattern as a function of angle is independent of the distance. The far field is generally characterized by an angular distribution of light intensity.

FIBER OPTIC CABLE: An optical fiber protected and augmented by protective layers (coatings, buffers, etc.), strength members, and an outer protective jacket.

FIBER OPTIC SYSTEM: The assembly of all the interconnected fiber optic subsystems, including sources, detectors, cables, couplers, and connectors.

GRADED INDEX FIBER: An optical fiber having an index profile in which the refractive index varies continuously as a function of radial distance from the longitudinal axis of the fiber. Graded index multimode fibers are used to minimize modal dispersion and improve the bandwidth.

INSERTION LOSS: The fraction of input power transmitted through a component in the link, normally expressed in dBs. For example, the insertion loss of a mated pair of connectors transmitting 90% of the incident energy is 0.46 dB. A coupling transmitting 50% of the input power has an insertion loss of 3.0 dB.

INTERCONNECT: Mating of optical fibers in a controlled manner using mechanical means to maintain accurate alignment of the optical fiber. (See CONNECTOR.)

JACKET: An outer polymer layer extruded over other components of a fiber optic cable (fiber, buffer coating, and strength members) to provide mechanical and environmental protection, and cable identification.

LAUNCH CABLE: A special jumper, serving to interconnect optical test equipment with an aircraft harness connector for testing the harness. The launch terminus may be a pin or socket. Also, see AMQJ. The integrity and cleanliness of the launch terminus should be checked prior to launch terminus insertion.

LAUNCH CONDITION: Defines the stimulus used when making fiber loss measurements with a stabilized light source and optical power meter.

LAUNCH CONDITION - OTDR: Accurate and repeatable loss measurements in short haul large core fiber, with concatenated connectors, require a special beam profile of the OTDR probe pulse.

LARGE CORE FIBER: Large core fiber is considered fiber with a nominal core diameter greater than 62.5 µm.

LINK LOSS BUDGET: The allocation of optical power and losses required by a system designer to meet the bit error rate under operating conditions in a fiber optic network. In more practical terms, the power budget is an expression of the optical power losses, combining elements of optoelectronic component performance and network topology, which allows assessment as seen by the receiver(s) as referenced in AS5603A. (See Appendix A.)

LOSS ACCURACY: The accuracy of a loss measurement made by an optical test instrument.

MAXIMUM THEORETICAL NUMERICAL APERTURE: A theoretical value of numerical aperture calculated using the values of refractive index of the core and cladding is given by:

$$NA_{\max} = \text{SQRT}(n_1^2 - n_2^2) \quad (\text{Eq. 1})$$

where:

n_1 = maximum refractive index of the core

n_2 = refractive index of the innermost homogeneous cladding

MODE: A mode of an axially uniform waveguide describes an optical field distribution whose amplitude in a plane normal to the fiber axis does not vary with axial distance along the waveguide, other than for the effects of a uniform attenuation.

MODAL LAUNCH CONDITIONER: Controls the modal launch conditions as a series of upper and lower limits at various radial positions.

MULTIMODE FIBER: An optical fiber which can support one or more bound modes in addition to the fundamental mode.

NEAR FIELD REGION: The region, close to the source or aperture, where the radiation pattern is dependent on the distance from the source, along the source axis. The near field is generally described by a spatial distribution of light intensity.

NUMERICAL APERTURE: The sine of the vertex angle of the largest cone of meridional rays that can be bound in an optical fiber system or element, multiplied by the refractive index of the medium in which the vertex of the cone is located.

OFDR: Optical Frequency Domain Reflectometer. Also referred to as an Optical Backscatter meter. High resolution and sensitivity reflectometer for short haul fiber networks, based on frequency scanning of a continuous wave.

OPTICAL FIBER: A cylindrical optical waveguide made from dielectric material.

OPTICAL INSPECTION MICROSCOPE – OIM: Passive optical magnification of the polished end of connector ferrule or the end of a fiber for viewing of condition, contamination, damage, or quality of the polish.

OPTICAL LINK: A fiber optic cable terminated at both ends with a connector/interconnect or connectorized fiber optic cables interconnected to each other.

OPTICAL POWER: The rate of flow of radiant energy with time.

OPTICAL POWER METER – OPM: Measures optical power emanated from an optical fiber.

OTDR: Optical Time Domain Reflectometer. Utilizes pulses of light injected into the fiber to analyze the back scattered light and characterize events along the fiber as a function of time, which multiplied by the effective group index is interpreted as distance. In aerospace, high resolution OTDRs, which can separate closely spaced events, must be used.

OVERFILLED CONDITION: An overfilled condition excites more than just the bound modes of a fiber, including cladding modes.

PASS/FAIL SOFTWARE: Analytical software providing fiber optic terminus end face inspection pass/fail criteria. Capable of producing detailed report of test results. Also, see VIDEO INSPECTION MICROSCOPE and VIDEO INSPECTION PROBE.

PC TYPE CONNECTORS: Physical Contact (PC) connectors, when mated, have their fiber end faces in contact, without an air gap. This is achieved by convex polishing the glass in the terminus. By eliminating the air gap, PC connectors have less reflection than gap type connectors.

POWER LINK BUDGET: The allocation of optical power and losses required by a system engineer to meet the bit error rate under operating conditions in a fiber optic network. In more practical terms, the power budget is an expression of the optical power losses, combining elements of optoelectronic component performance and network topology, which allows assessment as seen by the receiver(s). (See Appendix A.)

QUIET: A component, such as a connector, is referred to as “quiet”, if its return loss is greater than approximately 35 dB.

RAYLEIGH BACKSCATTER: In current aerospace conditions (where non-linear effects are negligible), the back scattering that is generated by microscopic density fluctuations along the fiber.

REAL TIME – OTDR: In real time operation the OTDR screen refresh rate is at least 30 Hz to enable troubleshooting intermittent faults.

RECEIVER: An opto-electronic device that converts optical power into electrical power.

RECEIVER SENSITIVITY: The minimum level of optical power required at the receiver to achieve the maximum allowable bit error rate during digital transmission.

REFRACTIVE INDEX (n): At a point in a medium, and in a given plane, the ratio of the velocity of light in a vacuum to the group velocity of a sinusoidal plane wave propagating in that given plane.

REFRACTIVE INDEX PROFILE: The distribution of the refractive index along a diameter of a cross-section of an optical fiber.

RESOLUTION, ONE POINT: One-point resolution is the smallest distance change a reflectometer can measure at a single isolated event.

RESOLUTION, TWO POINT: Two-point resolution is the smallest distance between two adjacent events of equal back reflection a reflectometer can measure.

RETURN LOSS: The fraction of input power over reflected power from any Event or from a complete link. In aerospace, as distances are short, for all practical purposes the return loss is generated by discrete reflections only. The typical return loss of an open flat polished connector is 14 dB, of a pair of mated gap type connectors is 11 dB, and of a pair of PC type connectors is 40 dB.

SHORT HAUL - AEROSPACE: A description applied to systems in which the propagation distance between source and detector reflects typical aircraft dimensions, i.e., less than 120 m.

STABILIZED LIGHT SOURCE – SLS: Injects a steady and known amount of optical power into a fiber under test.

STEP INDEX FIBER: Fiber with a refractive index profile characterized by a constant refractive index within the core and a sharp decrease, step function, in the refractive index at the core-cladding interface.

USABLE POWER: Power output from a transmitter that is of use to a receiver.

VIDEO INSPECTION MICROSCOPE – VIM: Equipment capable of displaying high resolution image of the end face of a fiber optic terminus for inspection purposes when used with a Video Inspection Probe. Also, see PASS/FAIL SOFTWARE and VIDEO INSPECTION PROBE.

VIDEO INSPECTION PROBE - VIP: Active method of viewing polished end of connector ferrule utilizing CCD technology to display the magnified image on a VIM and/or laptop computer for capture. See VIDEO INSPECTION MICROSCOPE and PASS/FAIL SOFTWARE.

VISUAL FAULT FINDER - VFF: Visible laser used to inject intense light into an optical fiber to check for continuity and to find fiber breaks.

VCSEL: Vertical Cavity Surface Emitting Laser

WAVELENGTH: The distance covered in a cyclic period by the wave front of a harmonic plane wave in a vacuum.

WAVELENGTH DIVISION MULTIPLEXING (WDM): The use of a multiplexer at the transmitter to combine several signals together through a given fiber optic cable path, and a de-multiplexer at a receiver to separate them apart.

6. FIBER OPTIC CABLE PLANT TEST

6.1 Fiber Optic Cable Plant Topology

The topology of a network refers both to its physical (cable plant) and logical (software) arrangement. Some typical topologies are shown in Figure 2. (Also refer to ARINC803, Section 3.2, Introduction to Network Topologies.)

6.1.1 Point-To-Point Cable Plant

The point-to-point cable plant is the basic building block of each of the following cable plant topologies. Topologies that are more complex can be broken down into point-to-point segments for individual link loss measurements and troubleshooting. The point-to-point topology is simply a single fiber optic cable with a fiber optic connection on each end. Information-containing light is transmitted from one end of the cable and received at the other end of the cable. Point-to-point topologies can also be made up of a series of cables with intermediate connectors between the transmit point and the receive point. This series of cables and connectors is usually referred to as a concatenated cable.

6.1.2 Star Coupled Cable Plant

The unique attribute of a star coupled cable plant is the use of a star coupler. A star coupler may be either transmissive or reflective and will have an equal number of input and output ports, creating an n-by-n star coupler with ports or fiber pigtails. Troubleshooting a star network with an OTDR may be more difficult than other cable plants due to the overlapping reflections from each output of the coupler. This difficulty can be overcome by having each pigtail of the coupler being of progressively longer length, thus shifting the returned reflections sufficiently that the OTDR can differentiate each event.

6.1.3 Ring Interconnected Cable Plant

A ring topology is a series of point-to-point connections between nodes in a network that are arranged in a closed loop. The ring topology can be troubleshot and tested in the same manner as a point-to-point cable plant.

6.1.4 Bus Topologies

A bus topology utilizes a fiber as a central line with a series of three-port tee couplers from which each node is tapped. Each tee coupler typically has a large offset ratio in which only a small percentage of the light is tapped off the bus to minimize losses through the network. If one of the couplers fails, the network is split into two networks in which the nodes can still communicate within each section but not between the two sections.

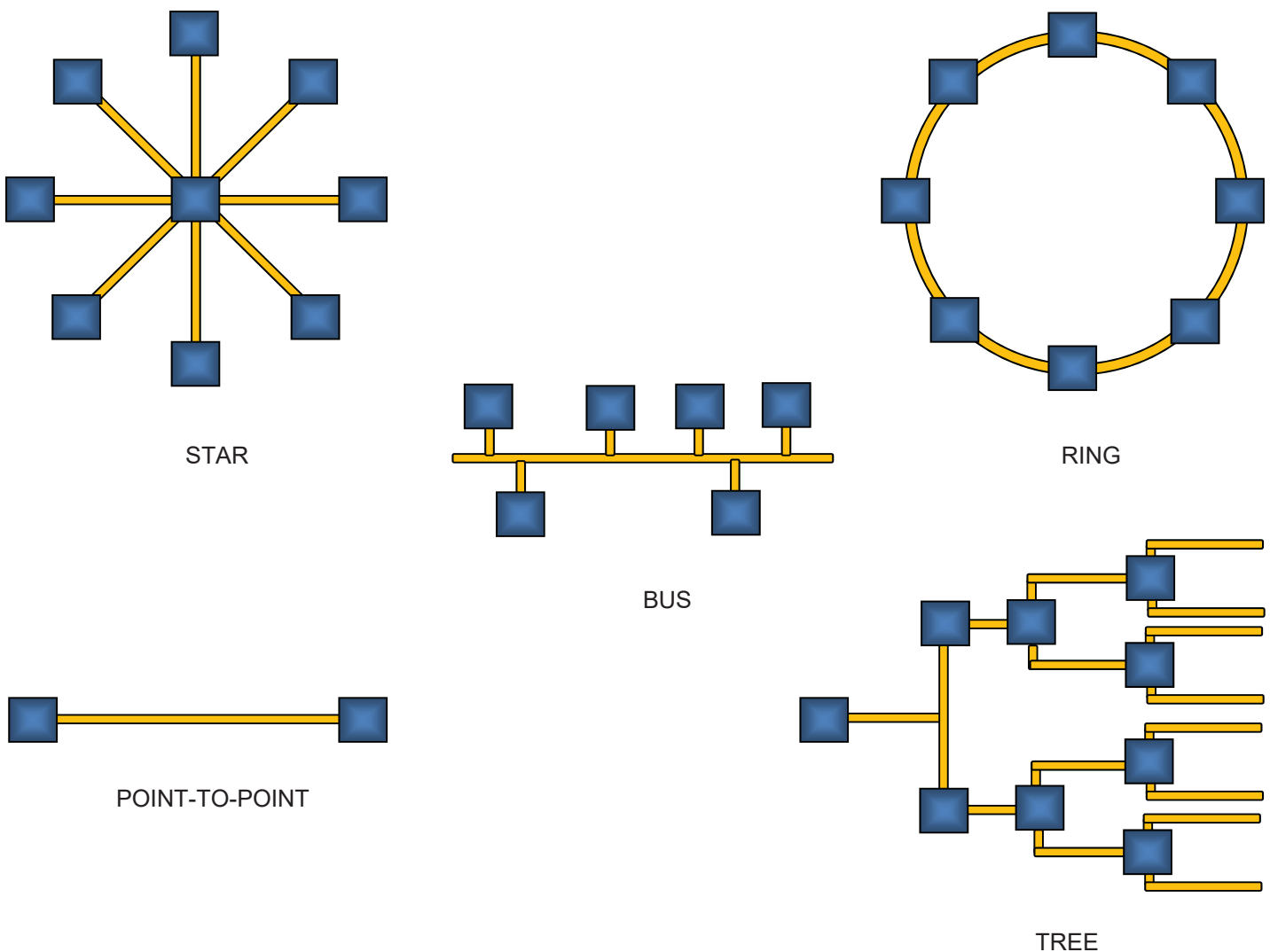


Figure 2 - Typical fiber optic cable plant topologies

6.1.5 Tree Topologies

Tree topologies can be most easily thought of as being like a typical cable television distribution system in which there is a main 'trunk' line with 'branches' out to subdivisions, then to blocks, then to homes. A disadvantage of tree topologies is that if there is a break in one of the branches, all nodes downstream from the break are affected.

6.1.6 Switch Coupled Cable Plant

The switches in a switched network route data from sources to destinations. To accomplish this, the switch examines the destination address in the signal frame header and then routes each frame to the proper destination. The switch controls the resources of the network by examining incoming frames in parallel. When contention for output resources occurs, the order in which frames depart the switch is based on their arrival time and priority/preference value. The switch also controls other network control functions such as providing the clock signal for the network. Here again, a switched network is a collection of point-to-point segments that can be easily troubleshot and tested between the switch and each node.