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# **Standard Testing Procedures for Optical Fiber and Unshielded Twisted Pair at Sandia National Laboratories**

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# **Standard Testing Procedures for Optical Fiber and Unshielded Twisted Pair at Sandia National Laboratories**

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## **Abstract**

This document will establish a working standard for testing optical fiber and unshielded twisted pair cables included in the Lab-wide telecommunications cabling system. The purpose of these standard testing procedures is to deliver to all Sandians a reliable, low-maintenance, state-of-the-art, ubiquitous telecommunications cabling infrastructure capable of satisfying all current and future telecommunication needs.

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## **Acknowledgment**

I would like to thank Jon A. Eberhart of Holmes and Narver Inc. His assistance in formalizing the information contained in this document, especially in the Unshielded Twisted Pair section, was greatly appreciated.

I would like to thank Bob Hoagland of Wavetek for offering his pioneering work in EUTP testing documentation.

## Preface

Since the early 1980s, the Communications Department has been installing optical fiber and unshielded twisted pair cables as part of the Secure data communications network. Recently, a major building recabling project was initiated at Sandia National Laboratories, New Mexico. This project consists of massive intra-building cable installations containing optical fiber and unshielded twisted pair cables. This project was the impetus for creating this testing procedures document.

This document defines standard testing procedures for optical fibers (both Multimode and Single Mode) and extended frequency unshielded twisted pairs. Adherence to these testing procedures will ensure the highest quality end-to-end transmission capability standard throughout Sandia's entire telecommunications infrastructure.

This document assumes manufacturer-recommended, hardware-specific installation and termination procedures have been implemented on associated components. The termination procedures included in this document incorporate some Sandia-specific modifications. Most of these modifications are products of several years of field installation experience. They have yielded superior end-to-end communications performance. Creating this high-quality standard telecommunications cabling infrastructure will greatly contribute to Sandia's ability to remain one of the premiere high technology research and development centers in the world.

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## Acronyms

10BaseF	10 Mbps baseband optical fiber media
10BaseT	10 Mbps baseband twisted pair media
AC	alternating current
ANSI	American National Standards Institute
ATM	asynchronous transfer mode
AT&T	American Telephone and Telegraph
AWG	American wire gauge
dB	decibel
dBm	decibels referenced to a milliwatt
CaA	cable attenuation in dB/km
CaL	cable length in kilometers
CoA	connector attenuation in dB
CoQ	connector quantity
CSMA/CD	carrier sense multiple access/collision detection
DC	direct current
DOE	Department of Energy
EIA/TIA	Electronic Industries Association/Telecommunications Industry Association
EMF	electromagnetic fields
EMI	electromagnetic interference
EUTP	enhanced unshielded twisted pair
FDDI	fiber distributed data interface
ft	feet
Gbps	gigabps, one billion bits per second
GHz	gigahertz, one billion cycles per second
HIGH-5	AT&T product designation for hardware capable of transmission rates up to 155 Mbps
Hz	Hertz, frequency in cycles per second
IBM	International Business Machines
IDR	intermediate distribution room
IEEE	Institute of Electrical and Electronics Engineers
KHz	kilohertz, one thousand cycles per second
Km	kilometer, one thousand meters
LAN	local area network
LED	light-emitting diode
Mbps	megabps, one million bits per second
MHz	megahertz, one million cycles per second
micron	one millionth of an inch
MM	multimode (optical fiber)
mV	millivolts, one thousandth of a volt
mW	milliwatt, one thousandth of a Watt
NEXT	near-end cross-talk
nm	nanometer, one millionth of a meter
NVP	nominal velocity of propagation
OF	optical fiber
OLTS	optical loss test set
ORL	optical return loss
OTDR	optical time domain reflectometer
PBX	private branch (or business) exchange

POF	plastic optical fiber
pf	picofarad, one trillionth of a farad (capacitance)
PTA	predicted total attenuation for optical fibers
RFI	radio frequency interference
RJ	registered jack
RMS	root mean square
SM	single mode (optical fiber)
SNL	Sandia National Laboratories
SNL/NM	Sandia National Laboratories/New Mexico
SOF	silicon optical fiber
SONET	synchronous optical network
ST	straight tip (optical connector)
STII	straight tip version 2 (optical connector)
TDR	time domain reflectometer
THz	terahertz, one trillion cycles per second
TSB	technical systems bulletin
TV	television
UL	Underwriter's Laboratories
USOC	Universal Service Order Code
UTP	unshielded twisted pair
VOM	volt-ohm-milliammeter

# Standard Testing Procedures for Optical Fiber and Unshielded Twisted Pair at Sandia National Laboratories

## Introduction

Past telecommunications cabling distribution systems at Sandia National Laboratories were designed and installed to meet simple transmission requirements. Voice and data transmissions typically required frequencies in the low KiloHertz (KHz) range. Today's technologies are requiring frequencies in the MegaHertz (MHz) range and rapidly approaching the GigaHertz (GHz) range. New cable infrastructures must be installed to meet these expanding bit-rate demands.

The capabilities of a modern cable infrastructure are primarily dependant on component quality and termination procedures. Components include cables, connectors, and couplers. Sandia's high-quality components are identified in SAND93-0002, *Intra-Building Telecommunications Cabling Standards for Sandia National Laboratories, New Mexico*. Maximum performance of these components can only be realized by proper installation and termination procedures. When installed and assembled, the components function as a single integrated unit or communications path.

All cable installation at Sandia will follow manufacturer-recommended installation procedures. Improper cable installation can drastically degrade the cable infrastructure capabilities by adding random inconsistencies, primarily frequency/bandwidth variations. All AT&T cable installations at Sandia will follow procedures described in AT&T's SYSTIMAX Premises Distribution System Installation Guidelines document.

All cable termination at Sandia will follow manufacturer-recommended termination procedures. Cable termination requires many sophisticated mechanical assembly techniques and the use of high-precision tools and test equipment. As with improper installation, improper termination techniques can also drastically degrade the cable infrastructure capabilities. For example, improper terminations can result in unacceptable attenuation and back reflections. The investment in high-quality components would be lost if termination procedures were not performed in a standard repeated method!

It is therefore absolutely necessary to adhere to the specific test procedures as defined in this document to assure ubiquitous capability, compatibility, expandability, reliability, and functionality throughout the Lab-wide telecommunications cabling infrastructure.

## Optical Fiber as a Transmission Media

### Background

In the past 20 years, a tremendous amount of research and design effort has been directed toward developing lightwave transmission. Lightwave transmission is based upon the physical principle of total internal reflection of light. A principle component of lightwave transmission is the actual lightguide, commonly referred to as an "optical fiber." Today's popular uses of optical fiber as a transmission media include voice, data, and video applications. Optical fibers offer many communication advantages such as: immunity

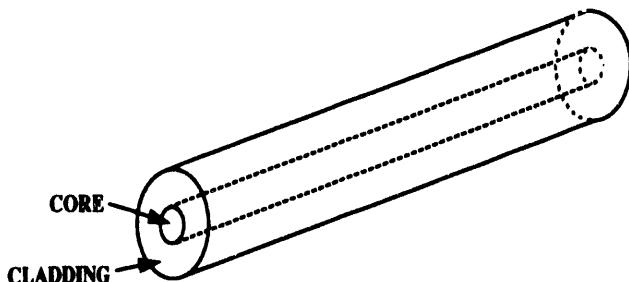
to external ElectroMagnetic Fields (EMF), minimization of signal coupling between adjacent conductors, the capability of withstanding caustic atmospheric environments, and most importantly, the propagation of very high bit-rate transmissions across long distances.

## Optical Components

Optical components utilized at Sandia include optical fibers, connectors, couplers, termination panels, and splices. Specific optical components to be used at SNL/NM are listed in SAND93-0002. The following is a general description of each component.

### Optical Fibers

An optical fiber is a cylindrically shaped light waveguide. Today, high bit-rate transmission optical fibers are typically made of doped silicon and sometimes referred to as Silicon Optical Fibers (SOFs). Plastic Optical Fibers (POFs) are currently being researched for high bit-rate applications; however, excessive internal optical attenuation has limited their deployment. Optical fibers are typically internally structured in two concentric regions, the core and the cladding. (See Figure 1.) The core material, having a slightly higher index of refraction than the cladding material, channels the light by the principle of total internal reflection. Total internal reflection is a physical phenomenon which occurs when light rays in the core region strike the core/cladding interface at less than the critical angle. These rays continue this reflection phenomenon and propagate the fiber.

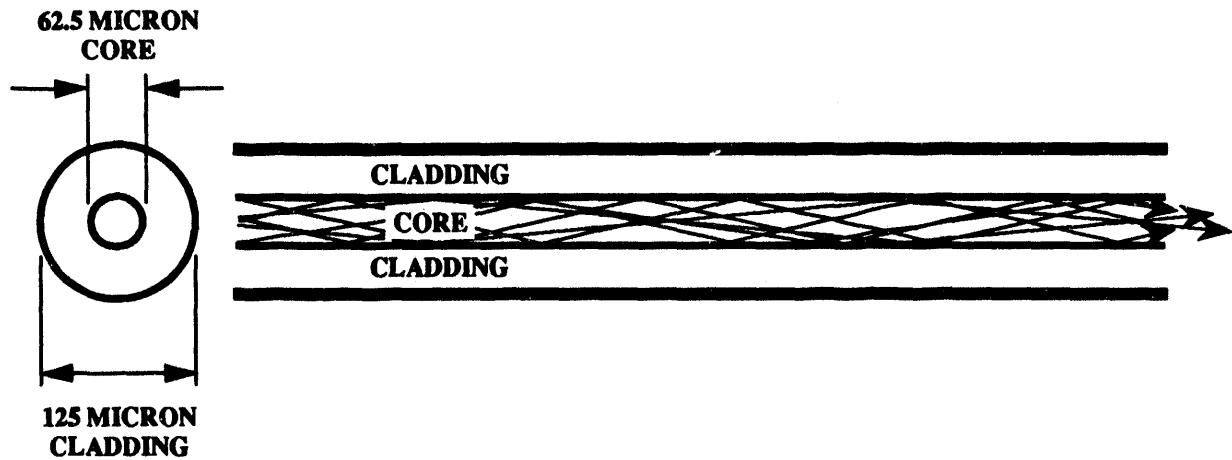


**Figure 1.** Optical Waveguide (commonly referred to as an optical fiber)

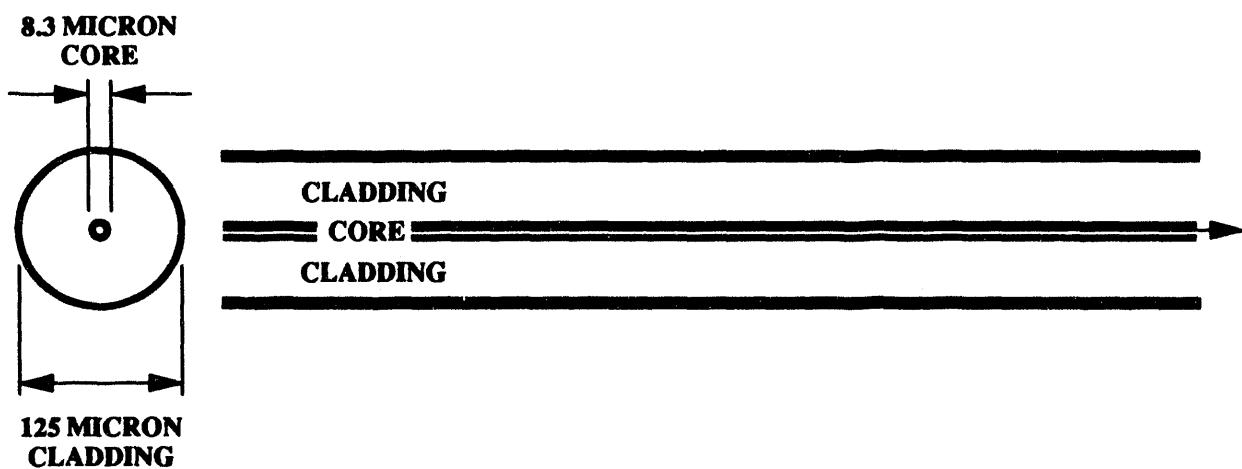
Optical fibers have evolved into two basic types, Multimode and Single Mode. These types of optical fibers have been incorporated within many national standards such as 10BaseF and FDDI. Newly developing standards such as Fiber Channel, SONET and ATM will also incorporate them.

Multimode fiber is manufactured to accept and propagate multiple modes (up to 1,000) or many light paths concurrently through the core material. (See Figure 2.) Mode propagation depends on physical parameters of the core such as 1) diameter, 2) numerical aperture, and 3) the injected light wave-length. Slight variations in propagation time of different modes of injected light result in "pulse spreading." As the frequency of light/no-light (representing digital ones and zeroes) increases, the length of the optical fiber must be decreased. The bandwidth of Multimode fiber is typically expressed as cycles per second for a given distance. Multimode fiber specified at Sandia is capable of at least 500 MHz/Km and has a core diameter of 62.5 microns with a cladding diameter of 125 microns. The ideal injected light wavelengths are 850 and 1300 nanometers (nm). These wavelengths correspond to low loss windows present in Multimode fiber.

Single Mode fiber is manufactured to theoretically accept and propagate a single mode (the axial mode) of light through the core material. (See Figure 3.) With one mode of light, there is virtually no "pulse spreading." This physical design parameter translates into extremely high bandwidth capability in the Terahertz range. The core diameter of Single Mode fiber specified at Sandia is 8.3 microns with a cladding diameter of 125 microns. Light propagating through a Single Mode fiber actually travels in a "mode field" which is slightly larger in diameter than the core. The mode field has an approximate diameter of 8.7 microns. This is a critical parameter if optimal connections are desired between two fibers. The ideal injected light wavelengths for Single Mode fiber are 1310 and 1550 nanometers. These wavelengths correspond to low loss windows present in Single Mode fiber.



**Figure 2.** Multimode Optical Waveguide (allows many paths of light to propagate)



**Figure 3.** Single Mode Optical Waveguide (allows one path of light to propagate)

## **Optical Connectors and Couplers**

To achieve maximum end-to-end transmission capabilities, optical connectors and couplers must match the physical parameters of the fiber they terminate. At Sandia, the standard optical connector and coupler for Multimode and Single Mode fiber is the ST (Straight Tip). Multimode and Single Mode ST connectors and couplers differ only in alignment component dimensional tolerances. Single Mode connectors and couplers have more precise tolerances and associated higher costs. These high-quality connectors and couplers have also been adopted by many national standards committees.

## **Optical Termination Panels**

There are two types of optical termination panels used at Sandia for intra-building cabling: the user outlets and the Intermediate Distribution Room (IDR) panels. Optical fiber panels must accommodate the number of cables and conductors required by the SAND93-0002 cabling standard.

The standard telecommunications cable configuration for each user outlet at SNL/NM is three 4-pair, high-quality, Unshielded Twisted Pair (UTP) cables; one 4-fiber Multimode cable; and one 4-fiber Single Mode cable. The standard user outlet is shown and described in SAND93-0002.

Buildings within Sandia's Secure Tech Area will be cabled with two identical cabling distribution systems: one black for Open/Restricted Access and one red for Secure telecommunications needs.

The standard IDR optical termination panel is capable of housing 24 optical fibers and is shown and described in SAND93-0002. Each IDR is capable of servicing hundreds of users. Therefore, the resultant number of optical fibers terminating in an IDR is high and requires extreme attention to space allocation for termination.

## **Optical Splices**

At Sandia, mechanical splices have been used for cable-cut emergency restoration. Fusion splicing is being used to minimize optical reflectivity in the Lab-wide Single Mode trunk which is nearing completion. Splicing will not

be discussed in this document because of its limited application.

## **Optical Test Equipment**

There are three basic types of optical test equipment used to verify installed end-to-end transmission capabilities. They are:

- Optical Loss Test Set or Optical Sources & Power Meters
- Optical Time Domain Reflectometer
- Optical Frequency Spectrum Analyzer.

## **Optical Loss Test Set (OLTS)**

An OLTS (commonly referred to as an attenuation meter) contains both an optical source and an optical power meter in one instrument. Optical sources and power meters with automated dual wavelength bi-directional attenuation and optical return loss (ORL) testing capabilities are preferred at Sandia for end-to-end testing of individual optical paths. An optical source typically injects a constant-wave frequency of light into an optical path. The power meter displays the amount of light received after propagating the optical path. The amount of light received is compared to the amount of light injected. The difference (minus the interconnection jumper losses) represents optical attenuation. It is most often expressed as power loss in units of decibels (dBs). It can also be expressed in units of milliWatts (mWs). The accuracy of the results is dependant on source and meter circuitry tolerances and operational procedures. Proper operational procedures, including consistency and frequent referencing, along with high-quality equipment can yield accurate, repeatable, power-loss measurements.

Optical attenuation is one of the most important transmission limitation factors for both Multimode and Single Mode fibers. ORL is an additional critical transmission parameter for Single Mode components due to the detrimental affect on LASER sources caused by reflections. Large back reflections can cause LASER sources to experience thermal variations which in turn cause both frequency and power stability problems. At Sandia, attenuation and ORL are measured with optical sources and power meters

incorporating dual wavelength bi-directional automated test features. This allows end-to-end testing of individual optical paths. Optical attenuation and ORL information obtained from this equipment is absolutely necessary for optical circuit design.

#### Optical Time Domain Reflectometer (OTDR)

Optical Time Domain Reflectometers can provide optical fiber and event loss as well as fiber length measurements. OTDRs contain both an optical source and a receiver. The ability to operate this device by a single person is an inherent advantage. OTDRs are excellent for immediate assessment of connector, splice, and fiber quality. They are indispensable for troubleshooting optical paths. Relatively large loss events (broken fibers, crashed/dirty connectors, etc.) can be located within inches or feet of their occurrence.

#### Optical Frequency Spectrum Analyzer

At Sandia, frequency spectrum analysis of an optical path is not typically required. The high-quality optical components (fibers, connectors, and couplers) required by Sandia bring with them guaranteed bandwidth specifications as stated by published manufacturing test results.

NOTE: The Attenuation/ORL test set included in the preferred test equipment listed in Table 1 incorporates both portability and accuracy. The OTDR incorporates extreme accuracy and has been used repeatedly in previous optical cable installations at Sandia. Optical test equipment other than the preferred items listed in Table 1 must be approved by Sandia Department 1955 prior to usage. All optical test equipment must be calibrated and certified in good working condition in accordance with the equipment manufacturers' recommendations.

**Table 1. Sandia-Preferred Test Equipment (November 1993)**

Equipment	Manufacturer	Model	Description
Optical Fiber Attenuation/ ORL Test Sets	EXFO	Multimode #FOT-913-12D-32	Dual Wavelength 850/1300 nm LED source with ST connector and InGaAs sensor
		Single Mode #FOT-913-BR23BLC-74	Dual Wavelength 1310/1550 nm Cooler LASER with ST/PC connector and InGaAs sensor
Optical Fiber OTDR	TEKTRONICS	TFP2 FiberMaster with plug-in modules	
		• Multimode FM8513-Option 24	Dual Wavelength 850/1300 nm source with ST PC connector
		• FM1315-Option 34	Dual Wavelength 1310/1550 nm source with ST PC connector
EUTP Cable Tester	Wavetek	LANTech 100	Multifunction tester capable of testing 100 Mbit Category 5 UTP
Note: As of November 1993, several other companies such as Microtest, Fluke, and HP are developing similar EUTP test equipment. This test equipment may prove to be acceptable, but must be approved by Sandia Department 1955 prior to use.			

## Optical Test Procedures

### Pre-test Training

Direct connectorization (assembling a connector onto the end of an optical fiber) involves many complex assembly procedures. Training facilities, typically operated by optical component manufacturers, offer certification for specific optical products. All personnel involved in optical connectorization activities at Sandia must be certified by training facilities approved by Sandia Department 1955.

### Test Data Forms

Sample forms for recording cable lengths, test data, and calculation results are included in the "FORMS" section of this document. These forms are available from Sandia Department 1955.

### Optical Cable Length Measurement

The length of each optical fiber cable must be determined from the length markings on the cable jacket. AT&T cable jacket markings are in feet; however, determining both the Predicted Total Attenuation and Calculated Optical Attenuation requires length in meters. All cable lengths in feet and meters must be included in the final report.

### Optical Test Equipment Setup

The optical test equipment must be properly adjusted prior to use. The user must follow the detailed setup instructions in the test meter instruction manual(s). The variable unit adjustments on the test equipment must be calibrated to match the cable manufacturer's stated cable transmission parameters. Typical OTDR setup requirements include inputting the cable's group index "N" as defined by the cable manufacturer.

The group index is a complex value based upon several optical cable properties: the test wavelength, refractive index profile, modal conditions (in Multimode fiber), and fiber length.

The index of refraction "n" for an optical fiber is defined as the speed of light in a vacuum "c" divided by the speed of light (or velocity of propagation) in the fiber "v." The typical value of "n" in fused quartz glass is 1.46.

### Connector Validation Test

As each optical connector assembly is completed, an OTDR must be used to assess immediate acceptance or rejection of the connector assembly. The connector assembly will be accepted if the loss displayed on the OTDR trace does not exceed the connector manufacturer's published mean loss and standard deviation value. Connector assemblies exceeding the manufacturer's mean loss and standard deviation value will be rejected. They must be replaced and tested with the OTDR until acceptance.

### Optical Reference Level Measurement

An optical source must be connected to a power meter with a short (2-3 meter) jumper cable. The jumper cable must have identical transmission characteristics as the optical path being measured. Operational stabilization (primarily thermal) must be reached by the optical sources prior to any measurements. After stabilization, the received power levels in dBm must be recorded. This procedure to obtain reference levels must be repeated every 30 minutes during the measurement process to verify the integrity of the jumper and the source. The same optical sources and power meters should be used for all measurements to ensure consistency.

### Optical Path Loss Measurement

End-to-end optical attenuation must be measured after both ends of an optical fiber have been connectorized, dressed and mounted in outlets or panels. This should represent a fiber's final physical configuration. At this point, the end-to-end attenuation can be measured and recorded with optical sources and power meters.

A source must be connected to one end (A) of the optical path to be measured and a power meter connected to the other end (B). The received power level (A to B) must be recorded in dBm for each applicable wavelength. The locations of the source and power meter must then be reversed. The received power level (B to A) must be recorded in dBm for each applicable wavelength. The two recorded power levels for each applicable wavelength must then be averaged and recorded in dBm. The reference level for each

wavelength must be subtracted from the average and recorded in dB. This value will be the "calculated optical attenuation" of the optical path for each wavelength.

This procedure must be repeated for all optical paths. All of the measured and calculated values must be included in a final report.

Additionally, all Single Mode optical paths must be measured for optical return loss. This can be accomplished by the use of the Sandia preferred attenuation/ORL test sets listed in Table 1.

#### Optical Path Acceptance Criteria

The "calculated optical attenuation" for each optical path must not exceed the Predicted Total Attenuation (PTA). The PTA must be calculated with the following formula:

$$\text{PTA} = (\text{CoQ} \times \text{CoA}) + (\text{CaL} \times \text{CaA})$$

where: PTA = Predicted Total Attenuation in dB

CoQ = Connector Quantity

CoA = Connector Attenuation in dB

CaL = Cable Length in km

CaA = Cable Attenuation in dB/km

The following values were derived from hardware vendor specifications:

#### CoA (MM or SM)

for STII connectors = 0.35 dB

CaA (MM) = 3.4 dB/km @ 50 nm

1.0 dB/km @ 1300 nm

CaA (SM) = 0.4 dB/km @ 1310 nm

0.3 dB/km @ 1550 nm

PTA calculation example for MM fiber at 850 nm:

$$\begin{aligned}\text{PTA} &= (2 \times 0.35 \text{ dB}) + (0.15 \text{ km} \times \\ &\quad 3.4 \text{ dB/km}) \\ &= 0.7 \text{ dB} + 0.51 \text{ dB} \\ &= 1.21 \text{ dB} \\ &= 1.2 \text{ dB rounded to nearest tenth of a dB}\end{aligned}$$

PTA calculation example for SM fiber at 1310 nm:

$$\begin{aligned}\text{PTA} &= (2 \times 0.35 \text{ dB}) + (0.15 \text{ km} \times \\ &\quad 0.4 \text{ dB/km}) \\ &= 0.70 \text{ dB} + 0.06 \text{ dB} \\ &= 0.76 \text{ dB} \\ &= 0.8 \text{ dB rounded to nearest tenth of a dB}\end{aligned}$$

Any optical path with a "calculated optical attenuation" exceeding its predicted total attenuation must be documented as unacceptable and the optical path problem must be identified and corrected.

The authority to abandon an unacceptable optical path after thorough attempts to correct the problem is solely owned by Sandia Department 1955.

#### Optical Return Loss Measurement

Single Mode connectors should have a median return loss of -42 dB and a maximum return loss of -35 dB. Any Single Mode connector with an ORL exceeding the maximum return loss must be replaced and tested until acceptance.

#### Final Optical Test Report

A final optical test report which confirms that the optical cabling infrastructure has been tested utilizing the procedures contained within this document must be delivered to Sandia, Department 1955, within 4 weeks after completion of the installation. The report must include cable test data, measurements and calculations for all installed cables as shown in the cable test forms in the "FORMS" section of this document. Sandia-preferred handheld test sets can perform many of the required tests simultaneously, greatly reducing testing time and labor costs.

The testing contractor must submit three copies of the test report. Optical fiber and UTP reports will be combined on the cable test forms.

Each report copy will be labeled and submitted in a white, 2-inch, three-ring view-binder. Each report copy will include:

- All completed cable test forms as described above, bound in order by room number.
- All certificates of optical test equipment calibration/certification.

- All certificates of training for test personnel.
- Any other information as needed to document the testing of the cable infrastructure.
- A written statement of compliance with SAND93-1076.
- A written statement assuring Optical Fiber and Unshielded Twisted Pair performance of the entire installation for a period of 5 years starting from the day of acceptance.

## Unshielded Twisted Pair as a Transmission Media

### Background

Before the advent of optical fiber, copper conductors were the prime choice for communications cabling. Even though better conducting materials were available (such as gold), copper provided the best balance between good conductance, cost, and material availability.

Today's technology allows data to be transmitted on Enhanced Unshielded Twisted Pair (EUTP) copper lines at 100 million bits per second and greater. At this speed, all the information contained in an entire set of encyclopedias could be transmitted in one minute! This high-speed data capability does not come easily. It requires high-purity copper, precision twisting of the wire pairs, careful installation, and matched precision components. Its primary limitation (derived from national and international standards) is a maximum transmission distance of 100 meters or approximately 300 feet. This makes EUTP an excellent option for intra-building cabling.

In spite of new high-speed UTP systems, optical fiber is still the preferred data transmission media for future communications systems. When compared to high-speed UTP systems, they can deliver even greater quantities of data, transmit over longer distances, and provide more immunity to external sources of interference. However, the new high-

speed UTP applications are currently useful for several reasons:

- UTP cabling is still convenient for use with existing copper-based equipment.
- UTP speeds are often satisfactory for systems that do not require massive quantities of data transfer.
- UTP is still more cost effective for short runs due to the relatively higher cost of optical fiber connectors and terminations.
- UTP cabling and electronic components are currently cheaper than comparable optoelectronic components, although the trend over the past 10 years has brought both costs much closer together.

### UTP Components

UTP components utilized at Sandia include copper cables, connectors, termination frames, patch panels, and splices. Specific UTP components to be used at SNL/NM are listed and described in SAND93-0002. The following are general descriptions of each component.

#### UTP Cables

UTP communications cables for high-speed applications may appear similar to regular telephone cables, but are in fact quite different. Extended frequency UTP cables are made of high-purity copper, have special precision pair twisting, and use special jacketing materials. Specialized installation procedures are also required as these cables are sensitive to bending, kinking, and overstressing.

Pair twisting is a critical parameter. The EUTP cables at Sandia consist of 4-pair cables. Each of the four pairs within a cable has a different angle of twist. This not only reduces crosstalk (signal coupling) between the two conductors of a pair, but also minimizes crosstalk between pairs within a cable.

EIA/TIA-569 TSB-40 specifies three high-speed UTP cable types for interior usage, and designates them as Categories 3, 4, and 5:

- Category 3 = max. 16 MHz, 10 Mbps.
- Category 4 = max. 20 MHz, 16 Mbps.
- Category 5 = max. 100 MHz, 100 Mbps.

AT&T has recently developed a 4-pair UTP cable capable of transmission rates up to 155 Mbps and beyond. AT&T designates this cable and associated termination components as their HIGH-5 product line. All 4-pair UTP cabling at SNL/NM is specified as AT&T HIGH-5 to provide maximum capability for any user who occupies a building at Sandia.

### **UTP Connectors**

As with optical connectors, UTP connectors must also match their cable's physical parameters to maintain the cable's maximum end-to-end transmission capability. For intra-building cabling at Sandia, the standard UTP connector is an AT&T HIGH-5 RJ-45 modular jack with pin configurations as designated per EIA/TIA-568, T568A.

### **UTP Termination Frames**

The IDR UTP frames must match their cable's physical parameters and accommodate the large number of cables and conductors required by this standard. Termination frames must accommodate Sandia's cable/conductor configuration and space limitation requirements. AT&T 110 termination frame and components are HIGH-5 and allow extremely dense termination of UTP conductors. This termination frame also provides consistent, reliable, repeatable, gas-tight connections for data, voice, and other low-voltage circuits. Each frame is capable of terminating 3600 wire pairs.

### **UTP Patch Panels**

Patch panels and jumper cables must also be HIGH-5 to maintain the UTP cables' data transfer capabilities. Patch panels, panel connectors, jumper cables, and jumper cable connectors are HIGH-5 RJ-45 modular jacks with pin configurations as designated per EIA/TIA-568, T568A or AT&T 110 termination components.

### **UTP Splicing**

At Sandia, splicing has been used for cable-cut emergency restoration, but is not a part of normal cable installation. Splicing is NOT permitted in any intra-building cabling and will not be discussed in this document because of its limited applications.

## **UTP Test Equipment**

There are eight basic types of UTP test equipment used to verify installed end-to-end transmission capabilities. They are:

- ohm meter
- terminators
- time domain reflectometer (TDR)
- noise meter
- line mapper
- high-frequency signal generator
- capacitance meter
- power meter

### **Ohmmeter**

The function of an ohmmeter is often included as part of a multimeter or volt-ohm-milliammeter (VOM). It is typically used to measure continuity of a conductor by testing for a short circuit or a known resistance applied across the opposite end of the conductor. Although ohmmeters are commonly used to validate coaxial cabling systems, they alone are not sufficient to validate unshielded twisted pair media.

### **Terminators**

Terminators end a cable segment under test by providing either a short circuit or several known resistances for matching wire pairs. Shorting terminators may not detect shorts due to cable damage. Impedance-matching terminators provide more reliable test information because they closely approximate actual system working conditions. Intelligent terminators contain on-board circuitry and can transmit and receive to work in conjunction with a handheld test meter.

### **Time Domain Reflectometer (TDR)**

A TDR is used to determine cable length and locations of impedance mismatch. It transmits a fast rise-time pulse down a conductor and then monitors for pulse reflections. Impedance mismatches cause reflections which can be displayed on an oscilloscope-like screen or a numerical display. While most defects cause minor reflections, the end of a conductor (or a break) produces a major reflection. The cable's length or the location of a defect may be calculated by combining a pulse reflection's travel time with the conductor's nominal

velocity of propagation (NVP). (Typically a fractional value of the speed of light, NVP is provided by the cable manufacturer.)

#### **Noise Meter**

A wide-band AC noise meter can detect problems from EMI and RFI by measuring the strengths of unwanted signals and analyzing the frequencies of induced line noise, thereby aiding in the identification of the noise sources. Although shielded cable is less susceptible to line noise than UTP, properly twisted UTP cable can provide reliable high-speed data transmissions at a lower cost. Installing the UTP cables in grounded metallic conduit can further reduce the cables' vulnerability to electronic disturbances. However, UTP can act as an antenna for electronic noise from such sources as fluorescent lighting, motors, broadcast equipment, and microwaves. UTP cabling should NOT be installed near these devices.

#### **Line Mapper**

Line mappers (or end-to-end connectivity testers) verify the end-to-end connectivity for each conductor in a UTP cable. Standard 4-pair UTP cables are terminated with an eight-pin modular jack (RJ-45) configured per EIA/TIA T568A. This cabling and connector set looks much like telephone wiring, but has a different wiring configuration. A line mapper uses a loop-back terminator and light-emitting diodes (LEDs) to verify proper termination. Advanced units also detect open and shorted circuits and provide conductor status printouts.

#### **High-Frequency Signal Generator**

A high-frequency signal generator simulates the live conditions of a fully loaded network. A stable, preset signal source is needed to accurately measure attenuation and crosstalk. A square wave output is needed to accurately simulate network data traffic, but a sine wave output can produce an effect adequate for obtaining characteristic cable performance measurements.

#### **Capacitance Meter**

A capacitance meter tests for conductor damage. It compares measured capacitance on

an open-ended cable pair with factory-specified nominal values or accepted industry-standard EIA/TIA values. A pair's mutual capacitance will change if it has been overstressed during installation.

#### **Power Meter**

The power meter receives input from the high-frequency signal generator. It measures the strength of the received signal at the far end of a pair. When the received signal strength is compared to the source strength, the transmitted power loss (attenuation) can be calculated. Near-end crosstalk may also be measured by attaching the signal generator and the power meter to the same end of different pairs.

#### **Multifunction Test Sets**

Modern technology has recently combined all of the required UTP test equipment into a single handheld unit. It is highly recommended that the UTP cabling tests be performed with the new multifunction handheld test units for several reasons:

- Individual test equipment pieces would cost approximately three-to-four times the cost of a single handheld multifunction unit.
- Handheld units are conveniently portable and easy to manipulate.
- Handheld units provide one-button multifunction autotesting and simple pass/fail results which reduce testing time and human errors.
- Handheld units can provide advanced features such as internal storage of many test results, variable printout options, and direct test data downloading into computer databases.
- Handheld units can have all test functions calibrated simultaneously by a single manufacturer.

### **UTP Test Procedures**

#### **Background**

Studies have shown that poor cable and connector installation practices can drastically de-

grade cabling performance. While cabling problems may account for 70 percent of all LAN problems, these cabling problems can be largely eliminated through proper cable installation and testing techniques. Expensive network downtime can be avoided and maintenance costs dramatically reduced when a cabling infrastructure is properly installed and tested.

The test procedures for UTP cabling are not as complex as the procedures for fiber-optic testing. However, EUTP cabling is far more sensitive than typical telephone cabling. For example, it cannot be kinked, stretched, or untwisted. EUTP must be more carefully installed and more rigorously tested to ensure its ability to transmit high bit-rates. Terminations and connections must be made in accordance with the cable and connector manufacturer's specifications. For example, the wire pairs cannot be untwisted more than 1/2 inch at the points of termination or crosstalk data errors will occur. All personnel involved in EUTP cable installation, termination, or connecting activities at Sandia must be fully aware of the hardware manufacturers' installation requirements and the following Sandia UTP test methods.

End-to-end testing must be measured after both ends of a cable have been connectorized and mounted in outlets, panels, or frames. This should represent a cable's final physical configuration. At this point, the required tests may be performed and the test information recorded for submittal in the final test report. Loss and interference values will encompass the sum of the end-to-end effects, including contributing factors from both the cable and the connectors. Cables and/or connector assemblies which do not test within the manufacturer's accepted test values will be rejected. They must be replaced and tested until acceptance. Each EUTP cable test is intended to have a simple pass or fail result as shown on the cable test forms in the "FORMS" section of this report.

#### Test Data Forms

Sample forms for recording cable lengths, test data, and calculation results are included in the "FORMS" section of this document. These forms are available from Sandia Department 1955.

#### Daily Test Equipment Preparation

UTP cable test equipment must be properly configured each day before testing begins. The following five checks must be made:

- Verify that the test equipment is still within its manufacturer's calibration warranty, as some manufacturers require that they annually recalibrate and recertify their test equipment.
- Verify that the tester is set to auto-test and the proper cable type is selected, e.g., 10BaseT, Category 3, 4, or 5.
- Verify that the tester's selected nominal velocity of propagation (NVP) matches the cable being tested. NVP values should be taken from each cable manufacturers' specifications. Average industry NVP values are shown in Table 2 for reference only.
- Perform a test meter "self-test" to confirm that the meter is functioning properly.
- Connect the tester to its matched "smart" terminator (via the test equipment manufacturer's test cable) and perform an auto-test to confirm that the meter and terminator are functioning properly together.

Table 2. Average Industry NVP Values

<u>Cable Type - NVP</u>	
10Base T	.65
16MB Token Ring	.71
4MB Token Ring	.65
EIA/UL Cat 3	.65
EIA/UL Cat 4	.71
EIA/UL Cat 5	.75
USOC	.65

After a successful series of these daily equipment checks, actual cable testing can begin. Use the appropriate test data forms in the "FORMS" section of this document to record the cable test results. Selecting the cable tester's auto-test fea-

ture with the Sandia-preferred test equipment should execute the following tests:

#### **Test #1 – Line Mapping (End-to-End Connectivity)**

A cable test meter is connected to one end of the cable to be tested and its terminator (commonly referred to as intelligent, smart, or remote) is connected to the other end of the cable. All four pairs are then checked for proper wiring configuration: open conductors, shorted conductors, crossed pairs, and reversed pairs. The results of these tests are recorded as either pass or fail for each pair. Failures require repair or replacement as necessary and retesting until passing results are achieved.

#### **Test #2 – Loop Resistance (DC – Steady State)**

An ohmmeter is connected across one end of a cable pair, with a shorting terminator across the other end of the cable pair. The steady-state DC resistance is measured in ohms and compared to the cable manufacturer's standard values. The permitted values and measured values will increase with longer segments of cable. The test equipment reports the ohms resistance value for recording. Values greater than the allowable resistance are considered fail. Values smaller than the allowable resistance will pass. The result of this test is recorded as either pass or fail. Failed tests include recording the measured resistance. Failures require repair or replacement and retesting until passing results are achieved.

#### **Test #3 – Near End Crosstalk (NEXT)**

NEXT is the tendency for signals travelling in one pair of wires to be induced into an adjacent wire pair. This effect is typically the greatest at connection points where the pairs are untwisted. NEXT is measured in dB. The amount of induced signal beyond the reference level is recorded. A source must be connected to one pair while an adjacent pair is tested. Impedance-matched terminators (100 ohms) should be used. The test frequencies and permitted dB crosstalk values at each tested frequency will be as specified in EIA/TIA TSB 36 for category five UTP cable. The results of the test will be pass or fail. Failed tests (crosstalk dB values smaller than those specified)

include recording both the measured crosstalk signal in dB and the frequency at which it failed. Failures require repair or replacement and retesting until passing results are achieved. It is not necessary to record passing NEXT values for the Signal-to-Noise Ratio (SNR) calculation if the test equipment automatically calculates and reports the SNR. Refer to the "Signal-to-Noise Ratio Test" at the end of this section.

#### **Test #4 – Attenuation**

Attenuation is measured by transmitting several signals at increasing frequencies across each conductor. The strength of the received signal is compared to the strength of the transmitted signal. The test equipment may physically measure millivolt signal loss, but should report the loss in units of decibels (dB). The signal loss will normally increase at higher frequencies. The test frequencies and permitted dB loss values at each tested frequency will be as specified in EIA/TIA 568 category five attenuation specifications for UTP cable. The results of the test will be pass or fail. Failed tests (attenuation dB values greater than those specified) include recording both the measured signal loss in dB and the frequency at which it failed. Failures require repair or replacement and retesting until passing results are achieved. It is not necessary to record passing attenuation values for the SNR calculation if the test equipment automatically calculates and reports the SNR. Refer to the "Signal-to-Noise Ratio Test" at the end of this section.

#### **Test #5 – Cable Length**

Cable length must be recorded from the length markings on each cable jacket. Lengths are currently marked in feet, and will also be recorded in feet. Cables longer than 295 feet (90 meters) should be noted in the length report as these cables may have data transfer limitations.

Cable length may be verified electronically with a time domain reflectometer (TDR) and the cable's manufacturer-specified nominal velocity of propagation (NVP). If an electronic TDR length verification is made, record any TDR cable length which measures more than 20 feet different than the recorded cable jacket length.

### Test #6 – Capacitance

When an EUTP cable is damaged, stretched, or improperly terminated, its mutual capacitance will change. Each twisted pair is tested with a capacitance meter. The opposite end of the pair being tested is open circuit. The capacitance between each wire pair (mutual capacitance) is measured and recorded in picofarads (pf). The measured capacitance is then divided by the cable length (recorded above from the cable jacket in the length test) to obtain the capacitance per foot (pf/ft). EIA/TIA TSB 36 limits the maximum mutual capacitance of category five UTP cable to 17 nf/1000 ft or 17 pf/ft. Properly installed UTP cabling should yield capacitance test results within 2 percent of the cable manufacturer's specification. The result of this test is pass or fail. An occurrence of a pair with mutual capacitance levels greater than 17 pf/ft is recorded as a failure. Failed tests include recording the measured mutual capacitance, and the cable and the failed pair in which it occurred. Failures require repair or replacement and retesting until passing results are achieved.

### Additional Testing

Additionally, the following tests may be useful for troubleshooting but are not required for cable certification when the above six tests have passed:

**Electrical Noise (EMI/RFI) Test.** Electrical noise is caused by random stray voltages induced into the data transmission cabling. There are two types of electrical noise tests: impulse noise and average noise.

The impulse noise test requires a voltmeter or oscilloscope to monitor each cable pair for more than 10 seconds and record any induced voltage surges or spikes with a duration of 20 nanoseconds or greater. IEEE 802.3 10BASET specifications define unacceptable impulse noise conditions as more than two occurrences of voltage greater than 264 millivolts within a continuous 10-second monitored time window. The result of this test is recorded as either pass or fail. Failed tests include recording the number of unacceptable spikes and surges within the 10-second testing window, and the millivolt value of the maximum recorded surge or spike.

Failures should be documented on the test forms.

The average noise test is made with a wide-band AC noise meter. The intent is to detect and identify EMI/RFI on the UTP lines. The cable being tested is terminated with its characteristic impedance (typically 100 ohms) and examined for EMI/RFI in three frequency bands:

- 0 Hz to 150 kHz (typical sources – AC lines, intercoms, telephones, blower motors, elevator equipment)
- 150 kHz to 20 MHz (typical sources – light dimmers, medical equipment, computers, copiers, laser printers)
- 20 MHz to 1 GHz (typical sources – radios, cellular phones, TVs, microwave ovens, broadcast equipment)

The result of this test is pass or fail. An occurrence of RMS noise levels greater than 100 millivolts in any of these three frequency bands is recorded as a failure. Failed tests include recording both the measured noise level in millivolts and the frequency band in which it occurred. Failures should be documented on the test forms.

**Cable Impedance Test (dynamic).** Impedance is the combined result from the dynamic effects of resistance, inductance, and capacitance. A cable's impedance will vary at different frequencies of data transmission. Cable manufacturers will list a nominal (average) impedance for their UTP cable at a specific frequency, for example, 100 ohms at 10 MHz. Each cable's absolute impedance will be measured via TDR technology at critical frequencies and appropriate incremental steps of frequency change. Each measured impedance will be examined and averaged along the length of the cable. For example, the sweep frequencies should be from 500 kHz through 100 MHz at incremental steps of 500 kHz. The results of the test will be pass or fail. The average measured impedance values at each test frequency must be within 15 percent of the manufacturer's specified values at each test frequency to pass; for example, a specified 100 ohms would pass if measured within 85 to 115 ohms. Note that split pairs may

exhibit 20 to 30 ohms impedance fluctuation, which will result in test failure. Failed tests include recording both the measured impedance in ohms and the frequency at which it failed. Failures should be documented on the test forms.

**Signal-to-Noise Ratio (SNR) Test.** The SNR is the mathematical value in dB of worst-case NEXT minus worst-case attenuation measured at the same test frequency. The results of the test will be pass or fail. Failed tests (SNR dB values smaller than 10 dB for 10BaseT or 5 dB for Cat.5) include recording both the calculated SNR value in dB and the frequency at which it failed. Failures should be documented on the test forms. Ideally, a passing NEXT and a passing attenuation should generate a passing SNR.

## Final UTP Test Report

A final UTP test report which confirms that the UTP cabling infrastructure has been tested utilizing the procedures contained within this document must be delivered to Sandia Department 1955 within 4 weeks after completion of the installation. The report must include pass/fail results and/or actual cable test data and required cable measurements and/or calculations for all installed cables as shown in the cable test forms in the "FORMS" section of this document.

Sandia's preferred handheld test units and intelligent terminators can perform many of the required tests simultaneously, greatly reducing testing time and labor costs.

The testing contractor must submit three copies of the test report. UTP and optical fiber reports may be combined if the cable test forms contain space to record both cable tests.

Each report copy will be labeled and submitted in a white, 2-inch, three-ring view-binder(s). Each report copy will include:

- All completed cable test forms as described above, bound in order by room number.
- An installer-signed statement of compliance with SAND93-1076.
- All certificates of UTP test equipment calibration/certification.
- All certificates of training for test personnel.
- Any other information as needed to document the testing of the cable infrastructure.
- A written statement of compliance with SAND93-1076.
- A written statement assuring Optical Fiber and Unshielded Twisted Pair performance of the entire installation for a period of 5 years starting from the day of acceptance.

# FORMS

# **BLACK** Outlet Cable Test Form

Building Number -	From: IDR Name -	To: Room Number -
Test Date -	Outlet Box Number -	Outlet Type -

## UTP CABLE

	Cable Length (ft) from Jacket marks	Test #1 Line Map	Test #2 Loop Resistance	Test #3 NEXT	Test #4 Attenuation	Test #5 Length	Test #6 Capacitance
VOICE CABLE	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail
DATA CABLE #1	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail
DATA CABLE #2	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail

## MM OPTICAL FIBER CABLE

Test Wavelength = 850 nm

Fiber #	Cable Length (ft) from Jacket marks	A to B loss dBm	B to A loss dBm	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____	_____

Test Wavelength = 1300 nm

Fiber #	Cable Length (ft) from Jacket marks	A to B loss dBm	B to A loss dBm	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____	_____

## SM OPTICAL FIBER CABLE

Test Wavelength = 1310 nm

Fiber #	Cable Length (ft) from Jacket marks	A to B loss / A ORL dBm / dB	B to A loss / B ORL dBm / dB	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____ /	_____ /	_____	_____	_____	_____
2	_____	_____ /	_____ /	_____	_____	_____	_____
3	_____	_____ /	_____ /	_____	_____	_____	_____
4	_____	_____ /	_____ /	_____	_____	_____	_____

Test Wavelength = 1550 nm

Fiber #	Cable Length (ft) from Jacket marks	A to B loss / A ORL dBm / dB	B to A loss / B ORL dBm / dB	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____ /	_____ /	_____	_____	_____	_____
2	_____	_____ /	_____ /	_____	_____	_____	_____
3	_____	_____ /	_____ /	_____	_____	_____	_____
4	_____	_____ /	_____ /	_____	_____	_____	_____

## Misc. Notes:

_____
_____
_____
_____

# RED Outlet Cable Test Form

Building Number -	From: IDR Name -	To: Room Number -
Test Date -	Outlet Box Number -	Outlet Type -

## UTP CABLE

	Cable Length (ft) from Jacket marks	Test #1 Line Map	Test #2 Loop Resistance	Test #3 NEXT	Test #4 Attenuation	Test #5 Length	Test #6 Capacitance
DATA CABLE #1	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail
DATA CABLE #2	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail
DATA CABLE #3	_____	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail	Pass / Fail

## MM OPTICAL FIBER CABLE

	Cable Length (ft) from Jacket marks	A to B loss dBm	B to A loss dBm	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____	_____

**Test Wavelength = 1300 nm**

	Cable Length (ft) from Jacket marks	A to B loss dBm	B to A loss dBm	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____	_____

## SM OPTICAL FIBER CABLE

	Cable Length (ft) from Jacket marks	A to B loss / A ORL dBm / dB	B to A loss / B ORL dBm / dB	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	/	/	_____	_____	_____	_____
2	_____	/	/	_____	_____	_____	_____
3	_____	/	/	_____	_____	_____	_____
4	_____	/	/	_____	_____	_____	_____

**Test Wavelength = 1550 nm**

	Cable Length (ft) from Jacket marks	A to B loss / A ORL dBm / dB	B to A loss / B ORL dBm / dB	Average loss dBm	Optical Reference Level (dB)	Calculated Optical Attenuation (dB)	Predicted Total Attenuation (dB)
1	_____	/	/	_____	_____	_____	_____
2	_____	/	/	_____	_____	_____	_____
3	_____	/	/	_____	_____	_____	_____
4	_____	/	/	_____	_____	_____	_____

## Misc. Notes:


## **BLACK IDR-to-Outlet Cabling Form**

**Bldg Number**

Office Outlet RJ45 positioning (left to right) Voice, Data 1, Data 2  
Skip 25th pair position on each 110 row to keep cable pairs grouped

<b>Box Number</b> Provided by 1955-1	<b>Room Number</b> Provided by Cable Installer	<b>Voice Frame Pairs</b> User Voice cable		<b>Data Frame Pairs</b> User Data cable #1		<b>Data Frame Pairs</b> User Data cable #2	
		From	To	From	To	From	To
		1	4	1	4	5	8
		5	8	9	12	13	16
		9	12	17	20	21	24
		13	16	26	29	30	33
		17	20	34	37	38	41
		21	24	42	45	46	49
		26	29	51	54	55	58
		30	33	59	62	33	66
		34	37	67	70	71	74
		38	41	76	79	80	83
		42	45	84	87	88	91
		46	49	92	95	96	99
		51	54	101	104	105	108
		55	58	109	112	113	116
		59	62	117	120	121	124
		63	66	126	129	130	133
		67	70	134	137	138	141
		71	74	142	145	146	149
		76	79	151	154	155	158
		80	83	159	162	163	166
		84	87	167	170	171	174
		88	91	176	179	180	183
		92	95	184	187	188	191
		96	99	192	195	196	199
		101	104	201	204	205	208
		105	108	209	212	213	216
		109	112	217	220	221	224
		113	116	226	229	230	233
		117	120	234	237	238	241
		121	124	242	245	246	249
		126	129	251	254	255	258
		130	133	259	262	263	266
		134	137	267	270	271	274
		138	141	276	279	280	283
		142	145	284	287	288	291
		146	149	292	295	296	299

## **BLACK IDR-to-Outlet Cabling Form**

**Bldg Number**

Office Outlet RJ45 positioning (left to right) Voice, Data 1, Data 2  
Skip 25th pair position on each 110 row to keep cable pairs grouped

<b>Box Number</b> Provided by 1955-1	<b>Room Number</b> Provided by Cable installer	<b>Voice Frame Pairs</b> User Voice cable		<b>Data Frame Pairs</b> User Data cable #1		<b>Data Frame Pairs</b> User Data cable #2	
		From	To	From	To	From	To
		151	154	301	304	305	308
		155	158	309	312	313	316
		159	162	317	320	321	324
		163	166	326	329	330	333
		167	170	334	337	338	341
		171	174	342	345	346	349
		176	179	351	354	355	358
		180	183	359	362	363	366
		184	187	367	370	371	374
		188	191	376	379	380	383
		192	195	384	387	388	391
		196	199	392	395	396	399
		201	204	401	404	405	408
		205	208	409	412	413	416
		209	212	417	420	421	424
		213	216	426	429	430	433
		217	220	434	437	438	441
		221	224	442	445	446	449
		226	229	451	454	455	458
		230	233	459	462	463	466
		234	237	467	470	471	474
		238	241	476	479	480	483
		242	245	484	487	488	491
		246	249	492	495	496	499
		251	254	501	504	505	508
		255	258	509	512	513	516
		259	262	517	520	521	524
		263	266	526	529	530	533
		267	270	534	537	538	541
		271	274	542	545	546	549
		276	279	551	554	555	558
		280	283	559	562	563	566
		284	287	567	570	571	574
		288	291	576	579	580	583
		292	295	584	587	588	591
		296	299	592	595	596	599

## ***RED IDR-to-Outlet Cabling Form***

**Bldg Number**

Office Outlet RJ45 positioning (left to right) Data 1, Data 2, Data 3  
Skip 25th pair position on each 110 row to keep cable pairs grouped

<b>Box Number</b>	<b>Room Number</b>	<b>Data Frame Pairs</b>					
		User Data cable #1		User Data cable #2		User Data cable #3	
Provided by	Provided by	From	To	From	To	From	To
1955-1	Cable installer						
		1	4	5	8	9	12
		13	16	17	20	21	24
		26	29	30	33	34	37
		38	41	42	45	46	49
		51	54	55	58	59	62
		63	66	67	70	71	74
		76	79	80	83	84	87
		88	91	92	95	96	99
		101	104	105	108	109	112
		113	116	117	120	121	124
		126	129	130	133	134	137
		138	141	142	145	146	149
		151	154	155	158	159	162
		163	166	167	170	171	174
		176	179	180	183	184	187
		188	191	192	195	196	199
		201	204	205	208	209	212
		213	216	217	220	221	224
		226	229	230	233	234	237
		238	241	242	245	246	249
		251	254	255	258	259	262
		263	266	267	270	271	274
		276	279	280	283	284	287
		288	291	292	295	296	299

## **RED IDR-to-Outlet Cabling Form**

**Bldg Number**

Office Outlet RJ45 positioning (left to right) Data 1, Data 2, Data 3  
Skip 25th pair position on each 110 row to keep cable pairs grouped

<b>Box Number</b> Provided by 1955-1	<b>Room Number</b> Provided by Cable installer	<b>Data Frame Pairs</b>					
		User Data cable #1		User Data cable #2		User Data cable #3	
From	To	From	To	From	To	From	To
	301	304	305	308	309	312	
	313	316	317	320	321	324	
	326	329	330	333	334	337	
	338	341	342	345	346	349	
	351	354	355	358	359	362	
	363	366	367	370	371	374	
	376	379	380	383	384	387	
	388	391	392	395	396	399	
	401	404	405	408	409	412	
	413	416	417	420	421	424	
	426	429	430	433	434	437	
	438	441	442	445	446	449	
	451	454	455	458	459	462	
	463	466	467	470	471	474	
	476	479	480	483	484	487	
	488	491	492	495	496	499	
	501	504	505	508	509	512	
	513	516	517	520	521	524	
	526	529	530	533	534	537	
	538	541	542	545	546	549	
	551	554	555	558	559	562	
	563	566	567	570	571	574	
	576	579	580	583	584	587	
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