THE TOLLY GROUP

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Berk-Tek/Ortronics Alliance

NetClear^{GT} Enhanced Category 5e UTP and NetClear^{GTO} Enhanced Multimode Fiber-Optic Cabling Solution Evaluation

Test Summary

Premise: *IT managers who are deploying networks utilizing fiber backbones and Unshielded Twisted Pair (UTP) Category 5e copper cabling to the desktop, so commonly deployed today, must be assured that these networks deliver reliable, standards-compliant error-free data transmission. Unshielded Twisted Pair (UTP) Category 5e copper cabling, multimode fiber-optic cabling and their respective connectivity components must be able to work together as a solution that meets or exceeds bit error rate (BER) limits as defined by the IEEE for running Gigabit Ethernet over copper and over multimode fiber.*

The NetClear^{GT} and NetClear^{GTO} cabling systems are the result of an alliance between Berk-Tek, an Alcatel Co., which provides copper and fiber cabling, and Ortronics Inc., a provider of copper and fiber connectivity products. The vendors have combined complementary products in an effort to provide cabling solutions that guarantee high-quality transport of Fast Ethernet and Gigabit Ethernet traffic.

Berk-Tek commissioned The Tolly Group to evaluate its NetClear^{GT} cabling system — which consists of Berk-Tek's LANmark-350 Enhanced Category 5e UTP cable and Ortronics GigaMo jacks, Category 5e patch panels and wiring blocks — in conjunction with its NetClear^{GTO} cabling solution, which consists of Berk-Tek's GIGAlite 62.5/125-µm multimode fiber-optic cable and Ortronics fiber patch panels and patch cords.

Test Highlights

- Delivers bit error rates within the IEEE requirements for running Gigabit Ethernet over copper and fiber cabling
- Complies with Berk-Tek's recommendation for a bit error rate of less than 10^{-11} for running Fast Ethernet over copper and the IEEE specification of 10^{-12} for Gigabit Ethernet over fiber
- Exceeds static/passive performance requirements specified by the TIA/EIA Category 5e standard and fiber-optic cable standard

Bit Error Rate (BER) Results for NetClear^{GT} Category 5e UTP Copper Horizontal Cabling and NetClear^{GTO} Multimode Fiber-optic Backbone Cabling:

Channel Compliance for Multi-topology Tests

Backbone Channel	Horizontal Channel	Cable	Connectivity	
NetClear^{GTO} Multimode Fiber-optic cable backbone (1000Base-SX)	NetClear^{GT} UTP Category 5e Copper Channel (100Base-TX and 1000Base-T)	Berk-Tek LANmark-350 UTP copper and GIGAlite fiber-optic cables	Ortronics, Inc. Category 5e and fiber patch panels, jacks, 110 wiring blocks, and patch cords	**All Samples PASS**
NetClear^{GTO} Multimode Fiber-optic cable backbone (1000Base-LX)				**All Samples PASS**

Source: The Tolly Group, August 2000 *Figure 1*

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The Tolly Group devised tests to measure the effective bit error rates encountered when running actual Fast Ethernet or Gigabit Ethernet traffic across the cabling plant under test. In the absence of a specific BER requirement for testing Fast Ethernet from the IEEE, Berk-Tek commissioned The Tolly Group to test Fast Ethernet to a BER of 10^{-11}, Gigabit Ethernet to 10^{-10}, which is the allowable BER level for Gigabit Ethernet over copper as defined by the IEEE 802.3ab and 10^{-12}, which is the allowable BER levels as defined in IEEE 802.3z for Gigabit Ethernet over fiber. Testing was performed in January 2000.

Test results show that when testing three segments of cable including Berk-Tek's Category 5e and multi-mode fiber-optic cables, with Ortronics connectivity products, the channels met or exceeded the BER requirements specified by Berk-Tek for Fast Ethernet and met or exceeded the BER requirements specified by the IEEE for Gigabit Ethernet over copper and multimode fiber.

Results

Linking Two Fast Ethernet Networks via a Gigabit Ethernet Backbone

The Tolly Group engineers tested a network consisting of two copper-based Fast Ethernet segments linked via a fiber-based Gigabit Ethernet backbone network. The two copper segments consisted of the NetClear^{GT} solution of LANmark-350 enhanced Category 5e cable and the multi-mode fiber-optic segment consisted of the NetClear^{GTO} solution of GIGAlite 62.5/125-µm multimode fiber. All three cable segments utilized Ortronics connectivity products.

Engineers sent bidirectional traffic consisting of 64-byte frames at 100% of the maximum theoretical packet per second (PPS) rate for Fast Ethernet and results demonstrated

Bit Error Rate of NetClear Multi-Topology Cabling Systems Channel Performance, 64-byte Frames:
Fast Ethernet to Gigabit Ethernet to Fast Ethernet

Horizontal Channel Type/Network Type	Backbone Network Type	Total Transmitted Frames	Total Frames Received Error-Free	Maximum Bit Error Rate
NetClear^{GT} Category 5e UTP	NetClear^{GTO} multimode fiber optic (1000Base-LX)	22,262,573,005	22,262,573,005	$<10^{-12}$
	NetClear^{GTO} multimode fiber optic (1000Base-SX)	24,971,708,651	24,971,708,651	$<10^{-12}$

Bit Error Rate of NetClear Multi-Topology Cabling Systems Channel Performance, 64-byte Frames:
All Gigabit Ethernet

Horizontal Channel Type/Network Type	Backbone Network Type	Total Transmitted Frames	Total Frames Received Error-Free	Maximum Bit Error Rate
NetClear^{GT} Category 5e UTP	NetClear^{GTO} multimode fiber optic (1000Base-LX)	21,273,773,494	21,273,773,494	$<10^{-12}$
	NetClear^{GTO} multimode fiber optic (1000Base-SX)	20,279,607,540	20,279,607,540	$<10^{-12}$

Note: During tests,The Tolly Group sent at least ten billion frames in each direction, that is approximately five trillion bits. One error in one trillion bits is equal to a bit error rate of 10^{-12}. Since all frames sent arrived error-free, all bits in each frame arrived error-free. Thus, the BER is measured at 10^{-12}.

Source: The Tolly Group, August 2000 *Figure 2*

that both the NetClear^{GT} and NetClear^{GTO} solutions maintained BER levels less than 10^{-13}. This remains in compliance with the IEEE BER level of 10^{-12} for Gigabit Ethernet over fiber, and 10^{-11} for Fast Ethernet over copper, as specified by Berk-Tek. See figures 1 and 2.

Note: The BER value of 10^{-13} is based upon aggregate bidirectional traffic. However, The Tolly Group verified IEEE BER compliance separately for transmissions in each direction during bidirectional traffic flow.

For tests with 1000Base-SX, the multimode fiber-optic portion of the channels demonstrated IEEE-compliant error-free transmission at 800 meters — 580 meters longer than the 220-meter IEEE requirement.

For tests with 1000Base-LX, the multimode fiber-optic portion of the channels demonstrated IEEE-compliant error-free transmission at 1,200 meters — 650 meters longer than the 550-meter IEEE requirement. See figure 3.

All Gigabit Ethernet

The Tolly Group engineers tested two segments of Gigabit Ethernet over copper connected by Gigabit Ethernet over fiber. The two copper segments consisted of the NetClear^{GT} solution of LANmark-350 enhanced Category 5e cable and the fiber-optic segment consisted of the NetClear^{GTO} solution of GIGAlite 62.5/125-µm multimode fiber. All three cable segments utilized Ortronics connectivity products.

Engineers sent bidirectional traffic consisting of 64-byte frames at 100% of the maximum theoretical packet per second (PPS) rate for Gigabit Ethernet and results demonstrated that both the NetClear^{GT} and NetClear^{GTO} multi-topology solutions maintained BER levels less than 10^{-13}, making the channels compliant with IEEE BER levels of less than 10^{-10} for Gigabit Ethernet over copper and 10^{-12} for Gigabit Ethernet over fiber. See figures 1 and 2.

For tests with 1000Base-SX, the multimode fiber-optic portion of the channels demonstrated error-free transmission at 800 meters.

For tests with 1000Base-LX, the multimode fiber-optic portion of the channels demonstrated error-free transmission at 1,200 meters. See figure 3.

Analysis

A given portion of a network — such as a UTP copper or multimode fiber network — may provide IEEE-compliant, error-free or "clean" transmission of data, but when three networks are linked together in a copper to fiber to copper network, a "clean" transmission becomes more difficult. The NetClear solution demonstrates that even though the traffic in this test traverses a three-segment network environment, the transmission remains "clean."

However, bit errors, and the frame errors that they produce, are cumulative. That is, an errored frame will be dropped by the next active device in the network. When the end-device ultimately detects the missing frame, it will need to signal the partner, which will then need to queue the frame for retransmission. In this test, for example, two 1000Base-T segments connected to a 1000Base-LX/SX segment via a pair of Layer 2 switches. If a bit error entered the network on any one of the segments, the resulting errored frame would be immediately discarded by the next switch or the end station. It would not be forwarded by a switch, nor be accepted by the end station.

As a result, errors on each of the three segments combine to produce an aggregate bit error rate for the entire network that may be, in theory, much higher than that of any individual segment. Specifically, an IEEE BER of 10^{-10} for a given segment translates to a predicted BER

Berk-Tek/ Ortronics Alliance

NetClear Cabling Solution

Functionality and Performance

TOLLY Up to Spec CERTIFIED

Berk-Tek/Ortronics NetClear^{GT} Enhanced Category 5e and NetClear^{GTO} Multimode Fiber-Optic Cabling Systems Product Specifications*

NetClear ^{GT} System Specifications

- Guaranteed channel capacity ≥ 1.2 Gbit/s
- Minimum usable bandwidth ≥ 155 MHz
- Independent third-party (ETL) static performance verification
- 25-year dynamic, static, and applications warranty

NetClear ^{GT} Component Specifications

Berk-Tek LANmark-350 cable

- ETL verified Cat 5e cable performance
- Tested to 350 MHz

Ortronics GigaMo jacks and panels

- ETL verified Category 5e channel performance
- Tracjack, Series II, or Mini-Mod

Ortronics GigaMo modular cords

- ETL verified Category 5e channel performance
- Backward compatible

NetClear^{GTO} System Specifications

- Guaranteed channel capacity ≥ 10 Gbit/s
- Guaranteed extended Gigabit Ethernet distances
  - 62.5/125 - 600 meters and 1200 meters at 850 nanometers and 1300 nanometers
  - 50/125 - 1000 meters and 2000 meters at 850 nanometers and 1300 nanometers
- Guaranteed free from bit errors caused by the cabling system
- 25-year dynamic, static, and applications warranty

For more information contact:
Berk-Tek, an Alcatel Co.
132 White Oak Rd.
New Holland, PA 17557
Phone: (877) 96-CLEAR
Fax: (717) 354-7944
URL: http://www.NetClear-channel.com

**Vendor-supplied information not verified by The Tolly Group*

of approximately 2 * 10^{-10} for a two-segment network.[1] In other words, a three-segment network consisting of two 100Base-T and one 1000Base-LX segments should deliver a BER of no more than approximately $10^{-10} + 10^{-10} + 10^{-12}$.

In fact, the tests show an aggregate BER significantly better than that specified by the IEEE for a single-segment fiber-optic Gigabit Ethernet link, indicating that the error rates for all segments were necessarily IEEE compliant.

Furthermore, the multi-segment test network involved two "off-the-shelf" Enterasys 10/100/1,000 Mbit/s Ethernet switches. That the results were encouraging in this configuration confirms that the results are not dependent upon specialized test equipment but rather remain consistent using an industry-standard switch.[2]

This means that customers who deploy multi-segment NetClear networks, with copper horizontal channels and fiber backbone channels, can expect to enjoy bit error rates well below those specified even for single-segment LANs. The tests showed no bit errors even after ten billion frames were transmitted across the network under test in both directions simultaneously (twenty billion frames total).

IEEE 802.3z Gigabit Ethernet Distance Specifications for Multimode Fiber-Optic Cable

Standard	Fiber Type	Core diameter (microns)	Modal bandwidth (MHz·km)	Minimum distance (meters)
1000Base-SX	Multimode	62.5	160	220 (1)
"	Multimode	62.5	200	275 (2)
"	Multimode	50	400	500
"	Multimode	50	500	550 (3)
1000Base-LX	Multimode	62.5	500	550
"	Multimode	50	400	550
"	Multimode	50	500	550
"	Singlemode	9	N/A	5,000

(1) ANSI/TIA/EIA-568-B.3 Commercial Building Telecommunications Cabling Standard, Section 4.4 ("Recognized cables")

(2) The international ISO/IEC 11801 building wiring standard specifies 200/500-MHz·km multimode fiber.

(3) The ANSI Fibre Channel specification specifies 500/500 MHz·km 50 micron multimode fiber. This fiber has also been proposed for addition to ISO/IEC 11801.

Source: Gigabit Ethernet Alliance, IEEE 802.3z Working Group, 1998 *Figure 3*

Test Configuration and Methodology

Prior to testing, The Tolly Group engineers verified that all capacity levels of the Category 5e cables met the industry passive-test standards for electrical performance as specified by TIA/EIA Category 5e standard. Engineers also verified that all of the multimode fiber-optic cable installations under test met the industry passive-test standards for optical performance as specified by the TIA/EIA 568-B.3 standard for optical-fiber cabling.

Engineers verified performance of the Category 5e cables with a Vigilant Networks 24-port Big Tangerine LM196 Network Channel Tester, software version REV 02 and a Fluke Corp. DSP-4000 Digital CableAnalyzer version 3.1. The DSP-4000 was also used to verify fiber-optic cables with the addition of a Fluke DSP-4000SR CableAnalyzer version 3.1 with a Fluke FTA410 Fiber Test Adapter.

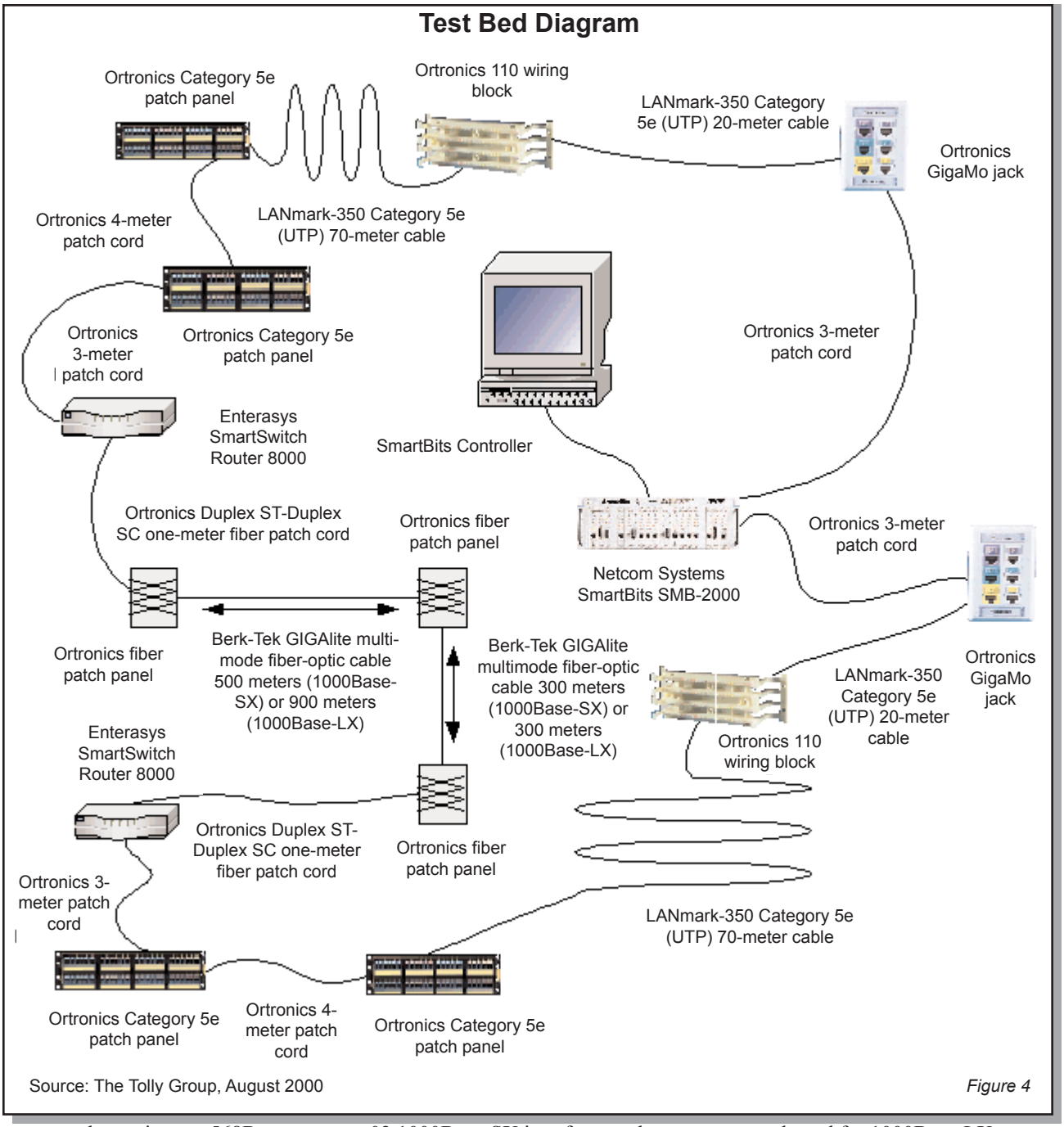
The copper test bed consisted of Berk-Tek's NetClear[GT] LANmark-350 Enhanced Category 5e UTP copper cables of 100 meters and Ortronics GigaMo connectivity products. A 20-meter portion of the LANmark-350 cable connected to an Ortronics GigaMo OR-63750001 Category 5e 568B jack at one end and an Ortronics 110 Wiring Block; model OR-30203506 on the other end.

A three meter Category 5e patch cord connected the jack to a Netcom Systems, Inc., a SPIRENT Communications Company, SmartBits SMB-2000 Advanced Multiport Performance Tester/Analyzer/Simulator, model SMB-2000 traffic generator, equipped with 100Base-TX and 1000Base-T interfaces, firmware version 6.61.12 that was connected to a 200-MHz Compaq Computer Corp. PC with 32 Mbytes of RAM and a PCI Bus card, running Microsoft Corp. Windows NT Workstation version 4.0 SP5 and Netcom Systems SmartWindows 6.53.18.

The Ortronics wiring block then

[1] The actual probablity of an error in a three-segment network, with probability of an error in any given segment of X, Y and Z, respectively, is *not* (X+Y+Z) but rather (X+Y+Z-X*Y-X*Z-Y*Z-X*Y*Z). However, when X, Y and Z are small (e.g., 10^{-10}), the multiplicative quantities in the above equation are virtually insignificant. Therefore, the approximation (X+Y+Z) is used here for simplicity and clarity.

[2] That is, if the SmartBits were, for instance, asserting non-compliant electrical signals on the cable that were too strong, errors would likely still have been introduced in traffic originating from the Enterasys switch. That no errors occurred on any segment suggests that the Enterasys switch, like the SmartBits, correctly decoded all received frames error-free.



Source: The Tolly Group, August 2000

Figure 4

connected to a six-port 568B Category 5e patch panel, model OR-60950004, via a 70-meter portion of the LANmark-350 Category 5e cable, which also connected to an identical Category 5e patch panel via a four-meter patch cord. The second Category 5e patch panel connected to an Enterasys Networks SmartSwitch SSR-8000, a Layer 3 switch, firmware version 3.0 equipped with the following interfaces: an SSR-HTX12-08 Fast Ethernet interface; an SSR-GSX11-02 1000Base-SX interface; and an SSR-GTX32-02 1000Base-LX interface.

A one-meter Duplex ST-Duplex SC multimode fiber patch cord connected the Category 5e test equipment to the SmartSwitch that connected to a multimode fiber-optic cable test bed.

The fiber test bed consisted of two lengths of Berk-Tek's GIGAlite 62.5/125-µm multimode fiber-optic cable. For 1000Base-SX tests, engineers tested an 800-meter cable sample and for 1000Base-LX tests, engineers tested a 1,200-meter cable sample.

For 1000Base-SX tests, engineers used a 500-meter segment of GIGAlite multimode fiber-optic cable and for 1000Base-LX, a 900-meter segment of cable that connected to two Ortronics, Inc. fiber patch panels model OR-615STDSM6C. One of the two patch panels connected to a third Ortronics fiber patch panel via a 300-meter segment of

GIGAlite fiber-optic cable. That patch panel also connected to the aforementioned Ortronics Duplex ST-Duplex SC patch cord. The other patch panel connected to a second one-meter Duplex ST-Duplex SC multimode fiber patch cord, which connected to a second Enterasys SmartSwitch SSR-8000, a Layer 2 switch, firmware version 3.0 equipped with the following interfaces: an SSR-HTX12-08 Fast Ethernet interface; an SSR-GSX11-02 1000Base-SX interface; and an SSR-GTX32-02 1000Base-LX interface.

The Enterasys switch connected to an Ortronics six-port 568B Category 5e patch panel, model OR-60950004, via an Ortronics three-meter patch cord. This patch panel connected to a second Ortronics Category 5e patch panel via a four-meter patch cord. A Berk-Tek LANmark-350 Category 5e (UTP) 70-meter cable connected the second patch panel to an Ortronics 110 Wiring Block, model OR-30203506. The wiring block connected to an Ortronics 20-meter portion of the LANmark-350 cable, which connected to an Ortronics GigaMo OR-63750001 Category 5e 568B jack. See figure 4.

For these tests, engineers generated a sequence of 64-byte frames, including the 4-byte Cyclic Redundancy Check (CRC), of bidirectional traffic at 100% of the theoretical maximum bandwidth across the cabling system.

The Tolly Group compared the number of frames transmitted with the number of error-free frames received to determine loss ratio. Engineers then calculated the BER by presuming that a frame that was lost, or contained an error, could have contained 100% bits that were in error. Based upon this presumption of a worst-case test result, The Tolly Group measured each system for its loss ratio — and therefore worst-case BER — relative to a required maximum.

The Tolly Group gratefully acknowledges the providers of test equipment used in this project.

Vendor	Product	Web address
Fluke Corp.	DSP-4000 Digital CableAnalyzer	http://www.fluke.com
Fluke Corp.	DSP-4000SR CableAnalyzer	http://www.fluke.com
Netcom Systems, Inc.	SmartBits SMB-2000	http://www.netcomsystems.com
Vigilant Networks	Big Tangerine	http://www.vigilantnetworks.com
Enterasys Networks	SSR-8000	http://www.enterasys.com

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Project Profile

Sponsor: Berk-Tek, an Alcatel Co.
Document number: 200220
Product class: Structured cabling systems
Products under test:

- Berk-Tek LANmark-350 Category 5e cable
- Ortronics Inc. Category 5e patch panel
- Ortronics Inc. GigaMo jack
- Ortronics Inc. 110 wiring block
- Berk-Tek GIGAlite 62.5/125-µm multimode fiber-optic cable
- Ortronics Inc. OR-615STDSM6C fiber patch panels
- Ortronics Inc. OR-6115OD62001M39C one-meter patch cords

Testing window: December 1999 through January 2000

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