
# Mixed High-Speed Ethernet Operations over Different Categories of Bundled UTP Cable

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# Introduction

As the market adoption of 10 Gigabit Ethernet (10GbE) continuously increases, more customers are deploying Category 6A/Class $E_A$ Unshielded Twisted Pair (UTP) cabling on top of Category 6/Class E UTP cabling. UTP cabling is the most widely deployed media around the world, supporting both data and voice applications. Even after the 10GBASE-T standard (IEEE Std. 802.3an™-2006) was ratified with Category 6A/Class $E_A$ UTP cabling as one of the supporting media, there are still discussions in the marketplace regarding assumptions and unanswered questions. Two frequently asked questions are:

1. Can Category 6A/Class $E_A$ UTP cable be mixed with Category 6/Class E UTP cable in the same bundle?
2. Can 10GBASE-T Ethernet applications co-exist in structured cabling bundles with 1000BASE-T Ethernet applications?

These questions are the primary concerns of many customers considering installation of Category 6A/Class $E_A$ UTP cabling and deployment of 10GBASE-T technology.

CommScope, Inc, a leading manufacturer of structured cabling systems, and Ixia, a leading manufacturer of Ethernet network testing equipment, are committed to fulfilling customer's needs and facilitating market adoption of 10 Gigabit Ethernet. CommScope and Ixia collaborated to address the reality of mixed-speed Ethernet running over different categories of bundled UTP copper cabling.

This white paper summarizes the details from testing worst case scenarios, methodology, system configurations, and equipment. It also addresses the concerns and unanswered question with test data, interpretations, and conclusions. Finally, it presents the reality and value to end-users, designers, consultants, integrators, and installers of Ethernet LAN and structured copper cabling systems.

# Executive Summary

There are many possible combinations of mixed-speed Ethernet running over different categories of bundled UTP copper cabling. The four worst case scenarios identified for testing are listed in Table 1. The "six-around-one" configuration is utilized with six "Disturber" cabling channels bundled around one "Victim" cabling channel. The Bit Error Ratio (BER) test is conducted on the Victim cabling channel while active traffic is running over the six Disturber channels. The Bit Error Rate (BER) is the ratio of bits received with error to the total number of bits transmitted. All 10G Ethernet PMDs/PHYs including 10GBASE-Tspecifies the same $10^{-12}$ BER. The BER test is a "Pass" when the BER is either zero or less than $10^{-12}$ for a statistically acceptable period of time. Table 1 summarizes the BER test results, cable categories and Ethernet speeds for each scenario.

| | Measured BER of Victim Channel | BER Test Duration | Victim Channel | Disturber Channel 1-3 | Disturber Channel 4-6 |
|---|---|---|---|---|---|
| Scenario 1 | 0 | 19 hr 44 min | CAT-6A/Class $E_A$ | CAT-6A/Class $E_A$ | [1]CAT-6/Class E |
| | | | 10GBASE-T | 10GBASE-T | 10GBASE-T |
| Scenario 2 | 0 | 17 hr 33 min | CAT-6A/Class $E_A$ | CAT-6A/Class $E_A$ | CAT-6/Class E |
| | | | 10GBASE-T | 10GBASE-T | 1000BASE-T |
| Scenario 3 | 0 | 18 hr 29 min | CAT-6A/Class $E_A$ | [1]CAT-6/Class E | [1]CAT-6/Class E |
| | | | 10GBASE-T | 10GBASE-T | 10GBASE-T |
| Scenario 4 | 0 | 8 hr 35 min | CAT-6A/Class $E_A$ | [1]CAT-6/Class E | CAT-6/Class E |
| | | | 10GBASE-T | 10GBASE-T | 1000BASE-T |

[1]Note: when using Category 6/ Class E cabling runs for 10GbE, the channel length is reduced 55 meters or less in accordance with IEEE 10GBASE-T, ISO TR 24750, and TIA TSB-155-A specifications.

The test results in Table 1 prove that 10GBASE-T Ethernet as an application running over the Victim Category 6A UTP cabling channel meets or exceeds the IEEE 10GBASE-T BER requirement, while mixed-speed Ethernet (10GbE or 1GbE) runs over the adjacent cables using different cabling categories (Category 6A/Class $E_A$ or Category 6/Class E).

So to answer the questions in the Introduction:

- Yes, Category 6A/Class $E_A$ UTP cable can be mixed with [1]Category 6/Class E UTP cable in the same bundle
- Yes, 10GBASE-T Ethernet applications can co-exist in structured cabling bundles with 1000BASE-T Ethernet applications.

# Methodology

The key concern in the questions stated in the Introduction is alien crosstalk between UTP cabling channels in close proximity to each other. Alien crosstalk is the electromagnetic noise that a cabling channel receives from adjacent cabling channels. If alien crosstalk noise is accumulated to a high enough level it could result in creating errors in network traffic or even the fatal problem of bringing the Ethernet link down, which has many upstream consequences for the IT Infrastructure manager. As UTP cable doesn't have the metallic shielding layer found in Foiled Twisted Pair (FTP) and Screened Twisted Pair (STP) cable, it is fair to raise a question about the capability of UTP cabling to meet alien crosstalk requirements.

One way to uncover alien crosstalk is to directly measure it and see if it is within the specifications defined in the ISO/IEC 11801 and ANSI/TIA- 568 standards. A "meet spec" channel performance is a guarantee that the passive cabling channel is clean and ready for Ethernet transmission. A limitation of measuring alien crosstalk performance is that it only covers the passive portion (the cabling) of a transmission system. It doesn't include the active portions, which are the electronic transceivers at the two ends.

A more comprehensive method is to measure the Bit Error Ratio (BER) of a real network transmission system. The BER tests measure the performance of transceivers and cabling channel, plus the PHY and MAC of the link partners on the transmission channels. The Bit Error Ratio (sometimes called Bit Error Rate) is the ratio of bits received with error to the total number of bits transmitted. The IEEE 802.3an-2006 standard, "10GbE Ethernet over twisted pair cable or 10GBASE-T," specifies a $10^{-12}$ BER. The $10^{-12}$ BER is defined as one or zero bits received with an error out of 1,000,000,000,000 (one trillion) bits transmitted. The $10^{-12}$ BER is specified in the IEEE standards for 10GbE and 1 Gigabit Ethernet (1GbE) over either fiber optic or balanced twisted pair copper media. The $10^{-12}$ BER is also adopted by many other standards outside of IEEE, such as INCITS Fibre Channel (T11) representing 10Gigabit Fibre Channel. In brief, the $10^{-12}$ BER is the key criteria to assess if a 10GbE Ethernet transmission system works properly or not.

The method of measuring BER is chosen from the tests described in this white paper.

In order to create a worst case alien crosstalk scenario, the "six-around-one" cabling bundle configuration is utilized. The "six-around-one" configuration as shown in Figure 1 is specified in ISO/IEC 11801 amendment 1 and ANSI/TIA- 568-C.2 standards. Each aqua-colored circle in Figure 1 denotes the cross-section of a UTP cable with four pairs of conductors wrapped in the jacket. The solid color and white dots represent a twisted pair. The colors blue, orange, green, and brown match the colors of the twisted pairs in a real cable.

Figure 1 illustrates the Victim cabling channel in the center that receives the alien crosstalk noise generated from the all adjacent Disturber channels. The alien noise level of the Victim channel is the highest among all of the channels in the bundle. The Victim channel has the worst case scenario in terms of alien crosstalk noise coupling.

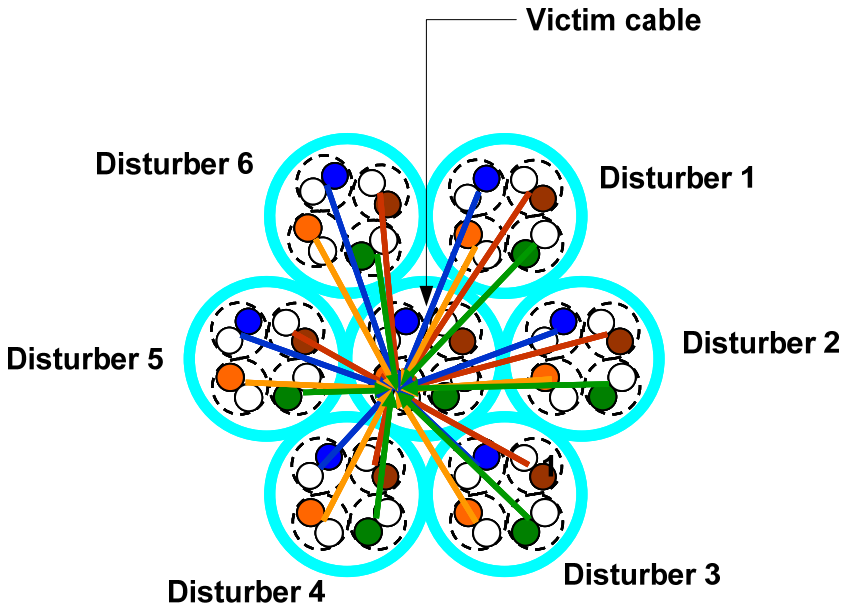



Figure 1 Six-around-one cable bundle configuration

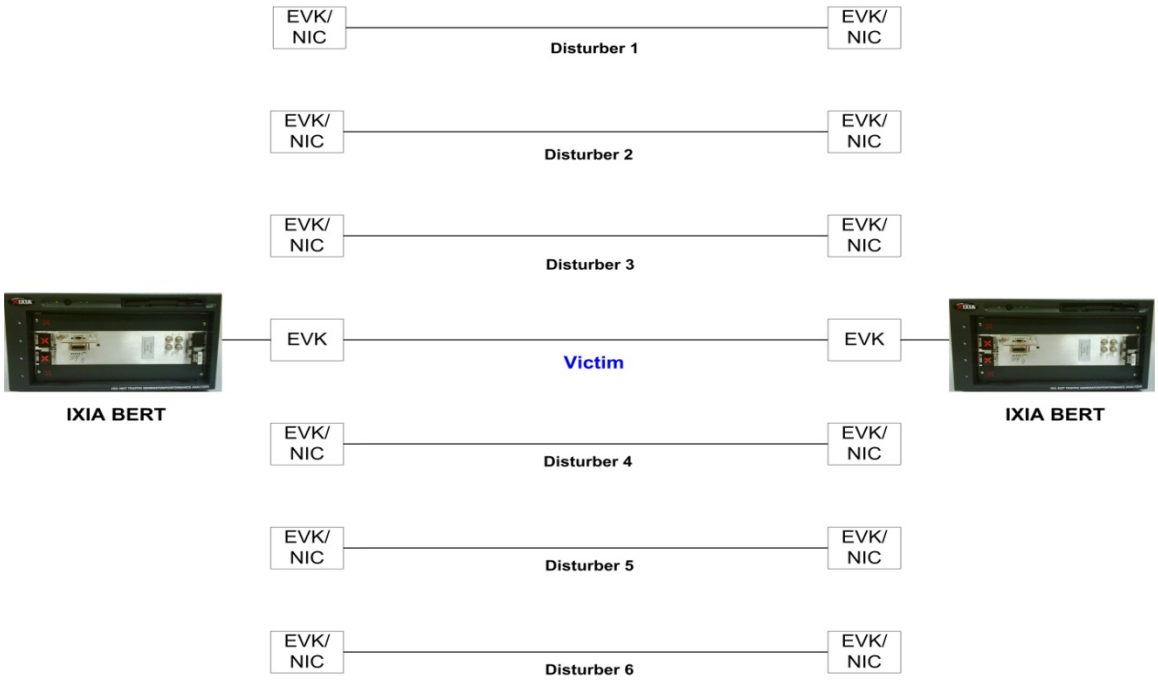
The BER tests are conducted on the Victim cable while continuous network traffic runs over the Disturber cabling channels.

The tests described in this white paper are conducted using CommScope Category 6A/Class $E_A$ and Category 6/Class E cabling solutions. All tests are also repeated on the equivalent cabling products from another UTP manufacturer. The purpose is not to show whose products are better, but to demonstrate if the testing results are consistent across different manufacturers' products.

# Testing Configurations and Equipment

The testing system configuration is illustrated in Figure 2. A pair of IXIA 400T chassis with 10GbE Load Modules are connected through the Victim channel. The IXIA 10GbE Load Modules can generate full duplex 10Gb/s Ethernet traffic at wire speed at the standard XAUI interface. The pair of PHY evaluation boards (EVKs) converts the Ethernet traffic to the 10GBASE-T layer 1 signals and send out over the victim cabling channel. Meanwhile, the IXIA Load Module can monitor, measure, and analyze the traffic in real time. The IXIA 10GbE equipment is utilized as the bit error ratio test (BERT) measurement system.

Six pairs of EVKs are utilized to generate continuous 10GBASE-T layer 1 patterned signals over the six Disturbers cabling channels. Whenever 1GbE traffic is needed for certain tests, 1000BASE-T network interface cards are utilized over the six Disturber cable channels. The network signals in the Disturber channels are used as the alien crosstalk noise for the IXIA 10GbE system to measure the BER's on the Victim cable.




All of the Victim and Disturber cabling channels have a three embedded connection configuration as shown in Figure 3. A connection is defined as a mated combination of an RJ45 jack and an RJ45 plug. The three connection channel configuration is the most commonly seen configuration in data centers. As shown in Figure 3, a structured cabling system includes patch cords, RJ45 jacks and plugs, and a horizontal cable. All of the Category 6A/Class $E_A$ cabling channels used in the test are 100 meters in length from end to end. The Category 6/Class E channels used to run 1GbE are 100 meters long. However, when using Category 6/ Class E cabling runs for 10GbE, the channel length is reduced 55 meters or less in accordance with IEEE 10GBASE-T, ISO TR 24750, and TIA TSB-155-A specifications that will sustain stable 10GbE Ethernet operations.

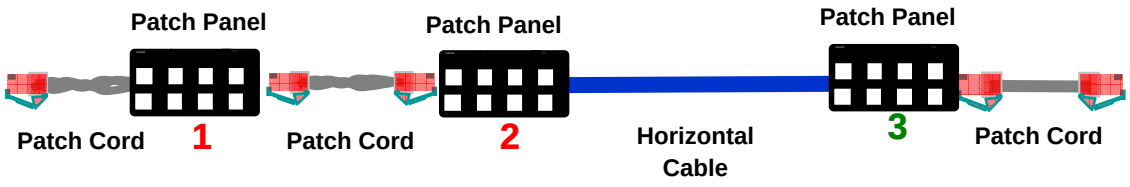



Figure 3 Three connection cabling channel configuration

Within any cabling channel of the Victim or the six Disturbers, all the cabling components have the same category rating from end to end. This ensures that a Category 6A/Class $E_A$ channel is constructed with Category 6A/Class $E_A$ cable and apparatus. Similarly, a Category 6/Class E channel is constructed with Category 6/Class E components from end to end. There is no mixing of different category

components within a channel. The mixture of different cabling categories occurs in a bundle, not within a channel.

In order to mimic the deployment of different category cables in a real world network for mixed speed Ethernet applications, the four testing scenarios are created as shown in Table 2.

| | Description | Victim Channel | Disturber Channel 1-3 | Disturber Channel 4-6 |
|---|---|---|---|---|
| Scenario 1 | Represent CAT-6A cabling channels that may exist in close proximity to CAT-6 channels. All of the channels run 10GBASE-T Ethernet. Measure the BER of 10GbE over the Victim | CAT-6A / Class $E_A$ | CAT-6A / Class $E_A$ | [1]CAT-6 / Class E |
| | | 10GBASE-T | 10GBASE-T | 10GBASE-T |
| Scenario 2 | Represent CAT-6A cabling channels that may exist in close proximity to CAT-6 channels. The CAT-6A channels run 10GbE while the CAT-6 channels run 1000BASE-T. Measure the BER of 10GbE over the Victim | CAT-6A / Class $E_A$ | CAT-6A / Class $E_A$ | CAT-6 / Class E |
| | | 10GBASE-T | 10GBASE-T | 1000BASE-T |
| Scenario 3 | Represent more CAT-6 cables that may exist in close proximity to CAT-6A cables. CAT-6 cable generally has a smaller diameter than CAT-6A cable. When CAT-6 cables run 10GBASE-T Ethernet, it is the extreme case in terms of alien crosstalk. Measure the BER of 10GbE over the Victim | CAT-6A / Class $E_A$ | [1]CAT-6 / Class E | [1]CAT-6 / Class E |
| | | 10GBASE-T | 10GBASE-T | 10GBASE-T |
| Scenario 4 | Represent more CAT-6 cables that are deployed in close proximity to CAT-6A cables. Some of the CAT-6 cables run 10GBASE-T while others run 1000BASE-T. Measure the BER of 10GbE over the Victim | CAT-6A / Class $E_A$ | [1]CAT-6 / Class E | CAT-6 / Class E |
| | | 10GBASE-T | 10GBASE-T | 1000BASE-T |

Table 2 Testing scenarios

[1]Note: when using Category 6/ Class E cabling runs for 10GbE, the channel length is reduced 55 meters or less in accordance with IEEE 10GBASE-T, ISO TR 24750, and TIA TSB-155-A specifications.

The consistent BER test results are observed across both manufacturers' products.

# Conclusions

An increasing number of 10GBASE-T products have entered the market. Users and designers have been evaluating the appropriate cabling media to support 10GBASE-T technology. Category 6A/Class $E_A$ and [1]Category 6/Class E UTP cables can be installed in close proximity or even in the same structured bundle. The 10GbE Ethernet application over Category 6A/Class $E_A$ cable will not be impacted by the 1GbE Ethernet application over Category 6/Class E UTP cable, and vice versa. Therefore, based on the BER tests, no issues or problems are found when mixing high-speed Ethernet operations over different categories of bundled UTP cable.

# About Ethernet Alliance

The Ethernet Alliance is a community of Ethernet end users, system and component vendors, industry experts and university and government professionals who are committed to the continued success and expansion of Ethernet. The Ethernet Alliance brings Ethernet standards to life by supporting activities that span from incubation of new Ethernet technologies to interoperability demonstrations, certification and education.

# Glossary

Category 6A: Telecommunications cabling or cabling components that are specified up to 500 MHz. The set of standards are managed under Telecommunication Industry Association (TIA)

Class $E_A$ : Telecommunications cabling that is intended to support a class of applications that use bandwidth up to 500 MHz. The set of standards are managed under International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

Category 6: Telecommunications cabling or cabling components that are specified up to 250 MHz. The set of standards are managed under Telecommunication Industry Association (TIA)

Class E: Telecommunications cabling that is intended to support a class of applications that use bandwidth up to 250 MHz. The set of standards are managed under International Organization for Standardization / International Electrotechnical Commission (ISO/IEC)

ISO/IEC 11801: Information technology - Generic cabling for customer premises

ANSI/TIA- 568-series: Telecommunications Cabling Standard

ISO/IEC 11801 amendment 1: Information technology - Generic cabling for customer premises amendment 1

ANSI/TIA- 568-C.2: Commercial Building Telecommunications Cabling Standard; Part 2: Balanced Twisted-Pair Cabling and Components

ISO TR 24750: Information technology – Assessment and mitigation of installed balanced cabling channels in order to support 10GBASE-T

TIA TSB-155-A: Guidelines for the Assessment and Mitigation of Installed Category 6 Cabling to Support 10GBASE-T, 2007: Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-T

PMD: Physical Medium Dependent sub-layer

PHY: Physical Layer Device