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SYSTIMAX® Solutions

GigaSPEED® X10D Solution **How**

White Paper
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at work

Contents

Modal Decomposition Modeling and the Revolutionary SYSTIMAX® GigaSPEED® X10D Performance

Modal Decomposition Modeling (MDM) is a sophisticated measurement and modeling tool, developed by CommScope Labs to analyze the interaction of all components comprising a channel. Modal decomposition recognizes all transmission modes that are naturally present in a multi-conductor transmission system, which results in a far more comprehensive understanding of the properties of a cabling channel.

The benefit of this innovative platform is not only measurement accuracy but also the ability to cascade individual components mathematically into a link or a channel. After collection of modal data for a large number of individual components, through a mathematical process, one can simulate a link or a channel as if all components were physically connected, and identify mode coupling and other weak links, in order to proceed to further refinement and system tuning. With this optimization of design, a U/UTP cabling system can sustain speeds in the multi-gigabit range without radical new design or footprint. This makes upgrading the infrastructure an evolutionary process, while achieving revolutionary performance.

SYSTIMAX GigaSPEED X10D cabling is designed to provide outstanding performance in a balanced circuit, through the use of advanced design tools including the MDM tool. With the MDM tool, CommScope Labs can see both common and differential modes on the cabling, including hundreds of interactions not yet defined in cabling standards, and if you can see these effects you have the ability to understand and optimize transmission capabilities. The design of the GigaSPEED X10D Solution is a leap forward in total system performance, with all the components exhibiting far superior end-to-end electrical performance - including superior crosstalk, loss and balance characteristics.

The performance of U/UTP cabling systems has traditionally been measured with high precision baluns, however this process has some serious limitations that are the result of calibration difficulties and balun bandwidth. To overcome the problems and limitations related to testing with baluns, a 16-port modal decomposition system was developed at CommScope Labs. In addition to traditional measurements such as Insertion Loss, NEXT, PSNEXT, ELFEXT, PSELFEXT, Return Loss, Delay and Delay Skew, this advanced technique can facilitate the measurement of highfrequency balance that has always been a very challenging problem for the cabling industry. This has proven extremely important for the bandwidth requirements of the GigaSPEED X10D Solution.

One of the main benefits of the GigaSPEED X10D Solution is substantial reduction in alien crosstalk (noise from adjacent cables and connectors), enabling the performance required for 10GBASE-T. The strength of the modal decomposition modeling is fully utilized by CommScope Labs to achieve this. By extending the concept of modal decomposition to encompass two devices side by side, the phenomenon of alien crosstalk between components such as adjacent cables or connectors is fully quantified. The result is a 32 x 32 matrix that is created from multiple 16-port modal decomposition measurements. All possible cross couplings between the two devices along with all possible mode conversions and scatterings are determined. Once the matrix is obtained, a thorough channel analysis can be easily performed using sophisticated modeling. When channels are examined with the MDM tool, the detailed mechanisms of channel alien crosstalk coupling are no longer a mystery.

MDM - An Introduction

There are two types of signals that can co-exist in a four-pair cabling system. Differential-mode signals have equal but opposite polarity when traveling on the two conductors of a pair while common-mode signals have the same polarity. Differential-mode signals are generally preferred, while common-mode signals are undesirable. Unfortunately, due to the imperfection of the transceivers, common-mode signals always exist. Imperfection in cable and connecting hardware can also create additional common-mode signals.

Common-mode noise can affect equipment in two ways. First it can directly affect equipment operation, such as locking up a computer. This happens because the common-mode signal gets directly inside the equipment and causes logical errors. This is due to poor equipment design and is independent of cabling.

Second, the common-mode signal can become converted to a differential-mode signal by the equipment and cabling. The critical parameter here is "balance" or alternatively "common-mode rejection ratio." The better balanced a circuit is, the less conversion from common-mode to differential-mode occurs.

The problem of common-mode noise is real and somewhat elusive. It becomes evident within an electronic system only when measured against the reference ground because it occurs equally and in phase on all signal lines with relationship to the reference ground. Many electronics manufacturers today use techniques such as common-mode termination on unused pairs to assist in controlling the amount of common-mode noise.

Differential-mode noise affects equipment primarily by corrupting transmitted signals on a balanced circuit. It can be directly coupled into a circuit or be derived from a common-mode signal.

Modal decomposition is a sophisticated tool to analyze the interaction of these signals. The concept of modal decomposition is based on a theory of multi-conductor transmission lines. When a differential or common-mode signal strikes a boundary, i.e. from a cable to a connector, it will be scattered into multiple waves. Some will continue to propagate through, while others will be reflected. These waves may be either differential-mode, common-mode or a combination of both. Modal decomposition recognizes all transmission modes that are naturally present in a multi-conductor transmission system. In a four-pair cabling system, the potential scatterings are described in a 16x16 reflection coefficient matrix denoted by p.

$$\rho = \begin{bmatrix} Differential \rightarrow Differential & Common \rightarrow Differential \\ Differential \rightarrow Common & Common \rightarrow Common \end{bmatrix}$$

The Differential ➔ Differential element is an 8x8 matrix. This matrix is fully defined by the cabling standards via four fundamental parameters of insertion loss, pr-pr NEXT, pr-pr FEXT and return loss. After proper computation, ELFEXT, PSNEXT, PSELFEXT, delay and skew can be derived from these basic parameters as well.

Balance issues have been considered in the standards over the last several years and have not moved forward because of the complexity of making consistent balance measurements. The Common ➔ Differential and the Differential ➔ Common element are both 8x8 matrices. They can be used to define the balance of the network. Unlike LCL and LCTL which examine mode conversion on the same pair, the modal analysis characterizes the cross coupling of different pairs as well.

The Common ➔ Common element can be used to define common-mode behavior. The definition of this matrix is very similar to that of the Differential ➔ Differential element. It also consists of the same four basic parameters as described above. However, it characterizes the reflecting and coupling effect among twisted pairs when commonmode signals are launched.

Modal measurements quantify all these modes and their interaction to help us understand the transmission phenomena occurring within and between cabling channels in much greater depth. The following chart and table illustrate the numbers of testing parameters specified by the standards for different categories of the cabling system and the comparison to the capabilities of the MDM tool.

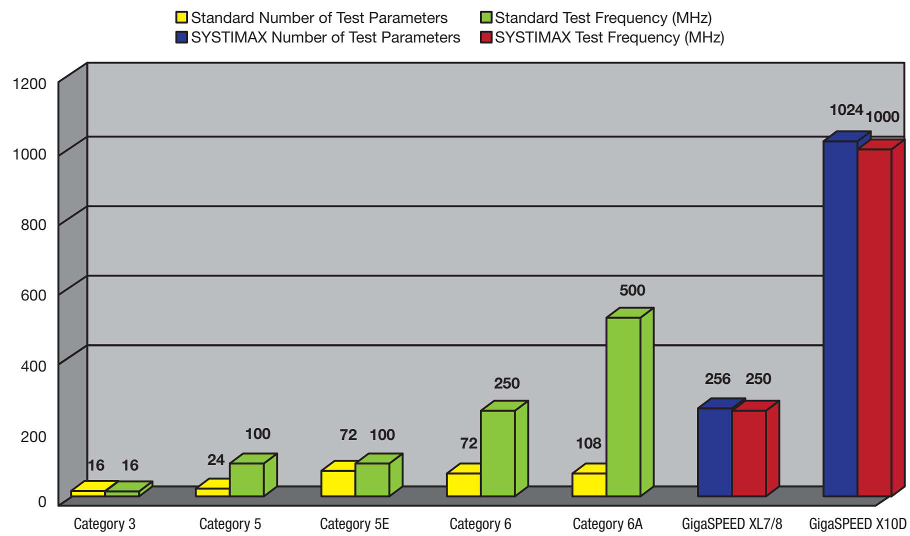


TABLE TITLE

Specification	Test Parameters	Test Frequency
Category 3	4 Attenuation, 12 NEXT, 16 Parameters Total	16 MHz
Category 5	4 Attenuation, 12 NEXT, 4 Delay, 4 Skew, 24 Parameters Total	100 MHz
Category 5E	4 Insertion Loss, 1 NEXT, 8 Return Loss, 4 Delay, 4 Skew, 24 ELFEXT, 8 PSNEXT, 8 PSELFEXT, 72 Parameters Total	100 MHz
Category 6	4 Insertion Loss, 12 NEXT, 8 Return Loss, 4 Delay, 4 Skew, 24 ELFEXT, 8 PSNEXT, 8 PSELFEXT, 72 Parameters Total	250 MHz
Category 6A	4 Insertion Loss, 12 NEXT, 8 Return Loss, 4 Delay, 4 Skew, 24 ELFEXT, 8 PSNEXT, 8 PSELFEXT, 8 TCL, 8 ELTCTL, 8 PSANEXT, 2 average PSANEXT, 8 PSAACRF, 2 average PSAACRF, 108 Parameters Total	500 MHz
GigaSPEED XL7/8	64 Differential Mode Terms, 128 Balance (Mode Conversion) Terms, 64 Common Mode Terms, 256 Parameters Total	250 MHz
GigaSPEED X10D	256 Differential Mode Terms, 512 Balance (Mode Conversion) Terms, 256 Common Mode Terms, 1024 Parameters Total	1000 MHz

Note: For any two adjacent components, 256 differential mode terms include 4 sets of 64 fundamental terms. Two of them characterize the internal differential coupling (i.e. IL, RL, NEXT and FEXT) of these components. The other two sets characterize the external differential coupling (i.e. alien NEXT and alien FEXT) of these components. The remaining 768 balance terms thoroughly record both internal and external cross-modal interactions and can be used to derive thousands of useful computed parameters highlighting transmission properties that have never been analyzed.

Since baluns are not involved in the process, the maximum testing frequency of this modal decomposition system depends on the actual bandwidth of the test instruments, which can be in the giga-hertz region. The MDM machine is already capable of characterizing channel performance up to 1000 MHz. This capability has been a key enabler for CommScope Labs in the development of the GigaSPEED X10D U/UTP solution, with performance specified up to 500 MHz in accordance with IEEE 802.3an 10GBASE-T requirements for insertion loss, PSANEXT and PSAELFEXT as well as internal channel parameters far exceeding the Category 6A/Class E_A requirements.

Applications of Modal Decomposition to the SYSTIMAX GigaSPEED X10D Solution

The benefit of this innovative platform is not only measurement accuracy but also its ability to cascade individual components mathematically into a link or a channel. Large samples of individual components including various types and lengths of cable, cordage and mated connections, are each characterized by a 16x16 matrix and the data files are stored in a computer. Virtual link and/or channels can be constructed by using these characterized components from a database of such measurements. Through a mathematical process, one can simulate links and/or channels as if all components were physically connected. Since the data of each component is stored in a 16x16 matrix, it is very easy to change the property of a component mathematically and visualize the impact of such a change on a large number of channels. A large-scale simulation process is able to predict the system performance of thousands of channels and the impact of design changes even before making a "real" prototype. More importantly, this unique capability provides valuable guidance to component engineers for their design iterations.

1. A System Design and Diagnostic Tool for Extended Frequency Performance

In practice, not all Category 6 links or channels will exhibit performance required by the 10GBASE-T standard up to 500 MHz. In most cases, performance degrades dramatically beyond 250 MHz. There is a false assumption that a link or a channel with existing Category 6 performance can be assured to meet the extrapolated specifications for all the common parameters such as insertion loss, crosstalk and return loss. Connectors compensated for 250 MHz but uncontrolled at 500 MHz may have strong interactions when the connectors are in close proximity, such as in a cross-connect or in short length channels. Thus a multi-connector channel may exhibit a high degree of scattering above 250 MHz. Under these conditions of poor connector design, degradation of system performance is inevitable.

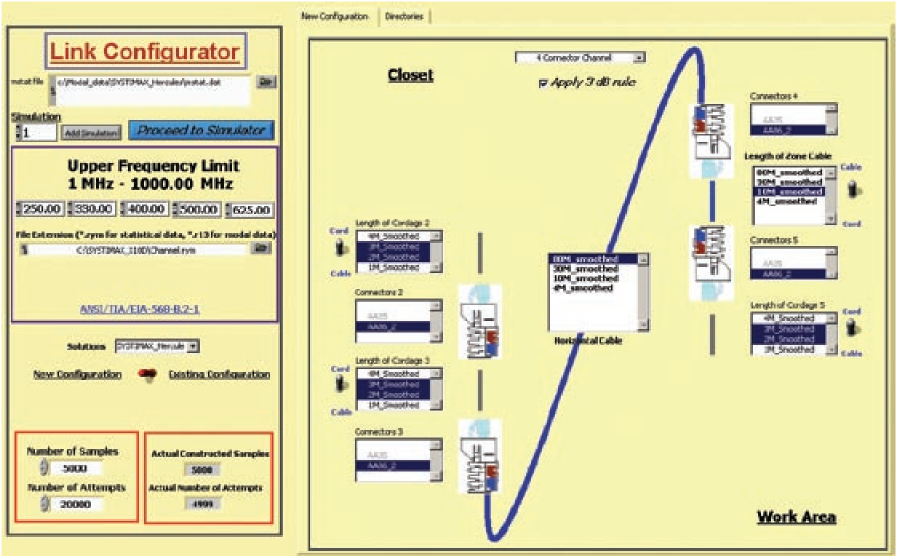
The root causes of performance degradation can be quickly determined via analysis of channel performance including all cross modal coupling paths. Once found these causes can be eliminated and the result is a tuned, balanced solution with optimum performance.

2. A Modal Cascade Simulator for Channel Performance

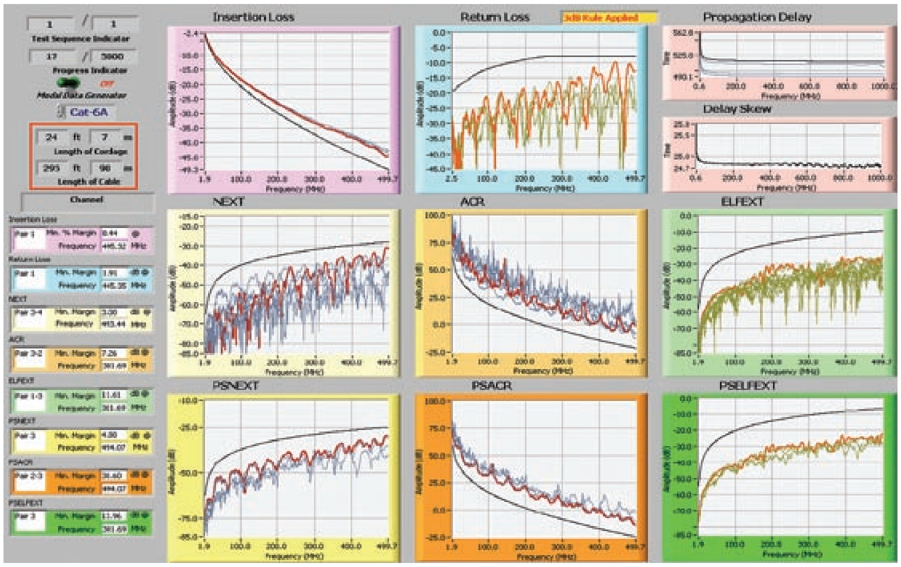
The only way to ensure that the GigaSPEED X10D channel specification is achievable is to verify the performance of all channel combinations

The guaranteed claims CommScope Labs makes for the GigaSPEED X10D Solution are derived from extensive modal simulation of worst-case conceivable configurations. Several component databases were built for modal cascade simulation and thousands of simulations are done for each channel or link configuration. A set of computer simulation programs was developed to run a Monte Carlo simulation on the performance of various cascaded links and channels. A sizable number of simulations (>5000) can be done within a short period of time. This powerful simulator allows CommScope Labs to assess link and channel performance to a level of detail that is far superior to that which the cabling industry has adopted at this time. There is no need to set up bulky links and channels for testing or sacrifice the sample size to accommodate space. Any large installation site with multiple link and channel configurations can be simulated. The prediction of the link and channel performance will be extremely close to the true population statistics. The following screen captures from the simulation programs illustrate this process.

a) Link Configurator - Allows engineers to choose a specific configuration. The number of simulations can be set arbitrarily. Components are picked at random from the database to configure a channel. The specific components selected for each channel are noted so that replicated configurations can be rejected automatically. When the number of simulations is set in the modal configurator (5000 in this case), it means 5000 distinctive channels will be simulated.

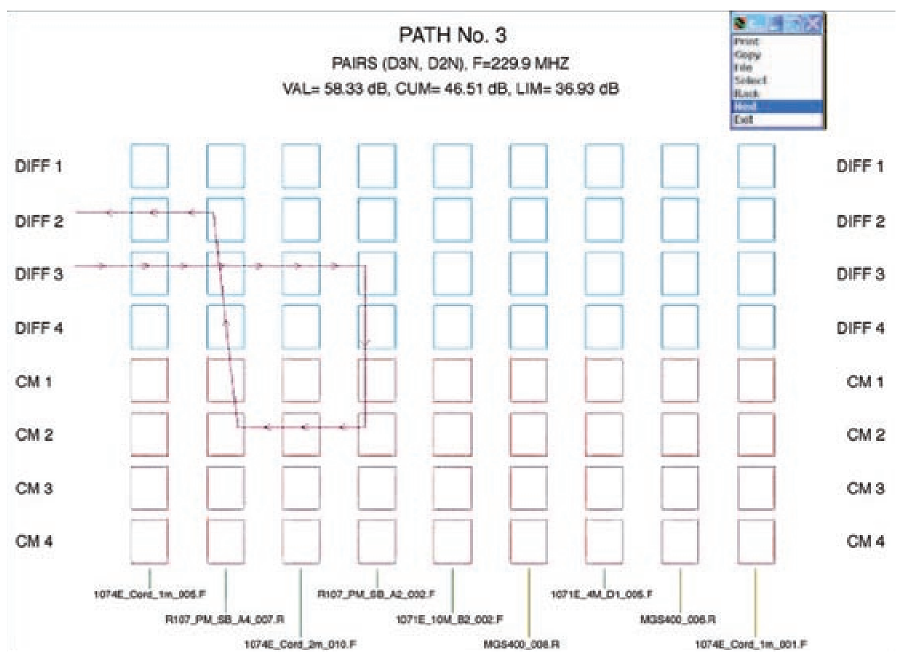


b) Modal Cascade Simulator – Channel or link performance of a pre-specified configuration is computed. The worst-case margin for each test parameter and the corresponding frequency are stored to a database. All traces are displayed on the graphs.

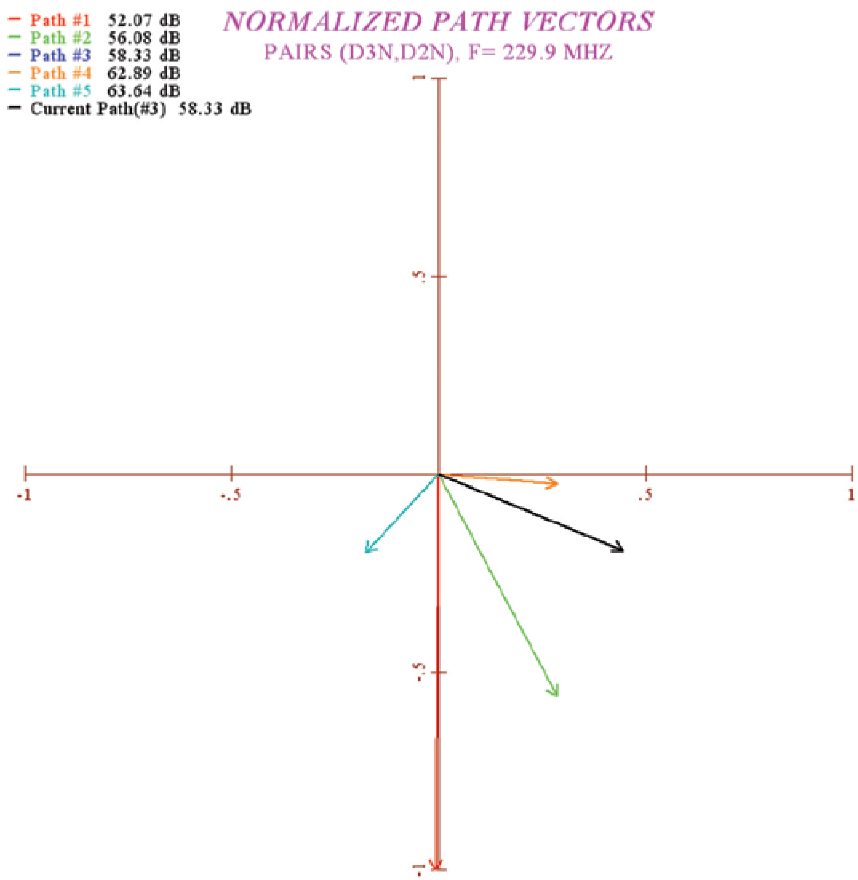


c) Statistics Analyzer – Based upon the simulation results, cumulative distributions and probability density functions are generated and plotted. The guaranteed claims of the GigaSPEED X10D Solution are derived from these statistics.

d) Path Analyzer – By utilizing the simulated channel results, this program is able to identify all coupling mechanisms, both internal and external, that affect the performance margin at any given frequency point. Depending upon the user's setting, all coupling paths can be displayed one after another by their rank in three different ways. This analysis tool starts a new era in cabling design. It allows the engineers to visualize how and why the cross-modal coupling occurs. Because of this important breakthrough, the GigaSPEED X10D Solution is capable of suppressing Power Sum Alien Crosstalk to meet the stringent requirements of the IEEE 802.3an 10GBASE-T Standard. The following figures illustrate the concept of this important design tool.



The figure shows a 4-connector channel under investigation. The components of the link are listed horizontally with the component names listed along the bottom of the plot. All of the possible transmission modes are listed vertically and range from differential on pair 1 to common-mode on pair 4. The minimum pr-pr NEXT margin for this particular channel occurs at 229.9MHz on pair 3-2. A path analysis tool examines all possible paths through the network connecting the differential port on pair 3 to the near end differential port on pair 2 and ranks them in order of severity. The analysis indicates that the third dominating contributor of this impairment (differential NEXT from pair 3 to pair 2) comes from the mode conversion of the connectors. The path analysis can be expanded to explore hundreds of paths until the sum of the individual path losses converge to the composite link performance value. MDM has proven to be the most valuable tool in the development of the GigaSPEED X10D Solution.



This normalized vector plot shows the significance of the path 3 coupling (black vector) compared to the strongest contributor, path 1 (red vector), and the second strongest, path 2 (green vector). Path 1 and 2 involve the differential-mode coupling only. Therefore, the impact of the cross-modal coupling just cannot be ignored any more.

Conclusion

The evolution and drive of networking to increasingly higher levels of performance and cost effectiveness is a never-ending path. CommScope Labs is committed to offer its unique expertise and proprietary design tools to ensure that customers can maximize their investment in CommScope Labs relative to the requirements of the Ethernet standards, and to continue leading the way with best-in-class U/UTP and fiber solutions for 10 Gigabit applications and beyond. CommScope Labs continues to deliver the industry's leading solutions through innovative technologies to maximize customer investment protection for the uncertain and rapidly changing future. We believe the GigaSPEED X10D Solution is the latest and greatest product to come out of a long line of CommScope innovations. The unique Modal Decomposition Modeling technology has enabled CommScope Labs to quantify and predict phenomena in the channel due to complex interactions among components that may not be detected with traditional testing technology. This insight highlights the challenge of achieving robust 10 Gb/s performance using only conventional design techniques. Our sophisticated system testing tools also highlight the fact that solving component challenges in isolation does not translate to a guarantee of end-to-end channel performance. Our refinements and system tuning optimizations has resulted in a best-in-class, robust U/UTP solution that meets all 10GBASE-T requirements – the GigaSPEED X10D Solution.

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