Screened and Shielded Cabling

– Noise Immunity, Grounding, and the Antenna Myth

Screened and shielded twisted-pair copper cabling has been around for quite awhile. A global standard in the 1980s, varieties of screened and shielded have remained a mainstay in some markets, while many others migrated largely to unshielded (UTP) cables.

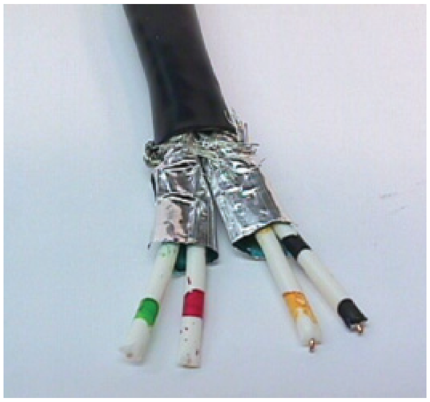
Recently, however, the ratification of the 10GBASE-T standard for 10Gb/s Ethernet over copper cabling has reestablished the commercial viability of screened and shielded systems and fueled greater adoption of these systems in previously UTP centric markets.

In this competitive landscape, many confusing and often contradictory messages are finding their way to the marketplace, challenging both cabling experts and end-users alike. This whitepaper addresses the most common questions, issues and misconceptions regarding screened and shielded cabling:

CHAPTER 1: Introduction and History of Shielding

In the 1980's, LAN cabling emerged to support the first computer networks beginning to appear in the commercial building space. These first networks were typically supported by IBM Token Ring transmission, which was standardized as IEEE 802.5 in 1985. Cabling for the Token Ring network consisted of "IBM Type 1" cable mated to unique hermaphroditic connectors. IBM Type 1 cable consists of 2 loosely twisted, foil shielded, 150 ohm pairs surrounded by an overall braid as shown in figure 1. This media was an optimum choice for the support of first generation LAN topologies for several reasons. Its design took advantage of the twisted-pair transmission protocol's ability to maximize distance (Token Ring served distances up to 100 meters) and data rates using cost effective transceivers. In addition, the foils and braid improved crosstalk and electromagnetic compatibility (EMC) performance to levels that could not yet be realized by early generation twisted-pair design and manufacturing capability. Not surprisingly, a handful of buildings are still supported by this robust cabling type today.

FIGURE 1: IBM. TYPE 1 CABLE



By 1990, LAN industry experts were beginning to recognize the performance and reliability that switched Ethernet provided over Token Ring. Concurrently, twisted-pair design and manufacturing capabilities had progressed to the point where individual foils were no longer required to provide internal crosstalk isolation and overall shields were not necessary to provide immunity against outside noise sources in the 10BASE-T and 100BASE-T bands of operation. The publication of both the 10BASE-T application in 1990 and the first edition ANSI/EIA/TIA-568 generic cabling standard in 1991, in conjunction with the lower cost associated with unshielded twisted-pair (UTP) cabling, firmly established UTP cabling as the media of choice for new LAN network designs at that time.

15 years later, as Ethernet application technology has evolved to 10Gbps transmit rates, a marked resurgence in the specification of screened and fully-shielded twisted-pair cabling systems has occurred. This guidebook addresses the practical benefits of screens and shields and how they can enhance the performance of traditional UTP cabling designs intended to support high bandwidth transmission. It also dispels common myths and misconceptions regarding the behavior of screens and shields.

CHAPTER 2: Balanced Transmission

The benefit of specifying balanced twisted-pair cabling for data transmission is clearly demonstrated by examining the types of signals that are present in building environments. Electrical signals can propagate in either common mode or differential (i.e. "balanced") mode. Common mode describes a signal scheme between two conductors where the voltage propagates in phase and is referenced to ground. Examples of common mode transmission include dc circuits, building power, cable TV, HVAC circuits, and security devices. Electromagnetic noise induced from disturbers such as motors, transformers, fluorescent lights, and RF sources, also propagates in common mode. Virtually every signal and disturber type in the building environment propagates in common mode, with one notable exception: twisted-pair cabling is optimized for balanced or differential mode transmission. Differential mode transmission refers to two signals that have equal magnitudes, but are 180° out of phase, and that propagate over two conductors of a twisted-pair. In a balanced circuit, two signals are referenced to each other rather than one signal being referenced to ground. There is no ground connection in a balanced circuit and, as a result, these types of circuits are inherently immune to interference from most common mode noise disturbers.

In theory, common mode noise couples onto each conductor of a perfectly balanced twisted-pair equally. Differential mode transceivers detect the difference in peak-to-peak magnitude between the two signals on a twisted-pair by performing a subtraction operation. In a perfectly balanced cabling system, the induced common mode signal would appear as two equal voltages that are simply subtracted out by the transceiver, thereby resulting in perfect noise immunity.

In the real world, however, twisted-pair cables are not perfectly balanced and their limitations must be understood by application developers and system specifiers alike. TIA and ISO/IEC committees take extreme care in specifying balance parameters such as TCL (transverse conversion loss), TCTL (transverse converse transfer loss) and ELTCTL (equal level transverse converse transfer loss) in their standards for higher grade (i.e. category 6 and above) structured cabling. By examining the performance limits for these parameters and noting when they start to approach the noise isolation tolerance required by various Ethernet applications, it becomes clear that the practical operating bandwidth defined by acceptable levels of common mode noise immunity due to balance is approximately 30 MHz. While this provides more than sufficient noise immunity for applications such as 100BASE-T and 1000BASE-T, Shannon capacity modeling demonstrates that this level provides no headroom to the minimum 10GBASE-T noise immunity requirements. Fortunately, the use of shielding significantly improves noise immunity, doubles the available Shannon capacity, and substantially increases practical operating bandwidths for future applications.

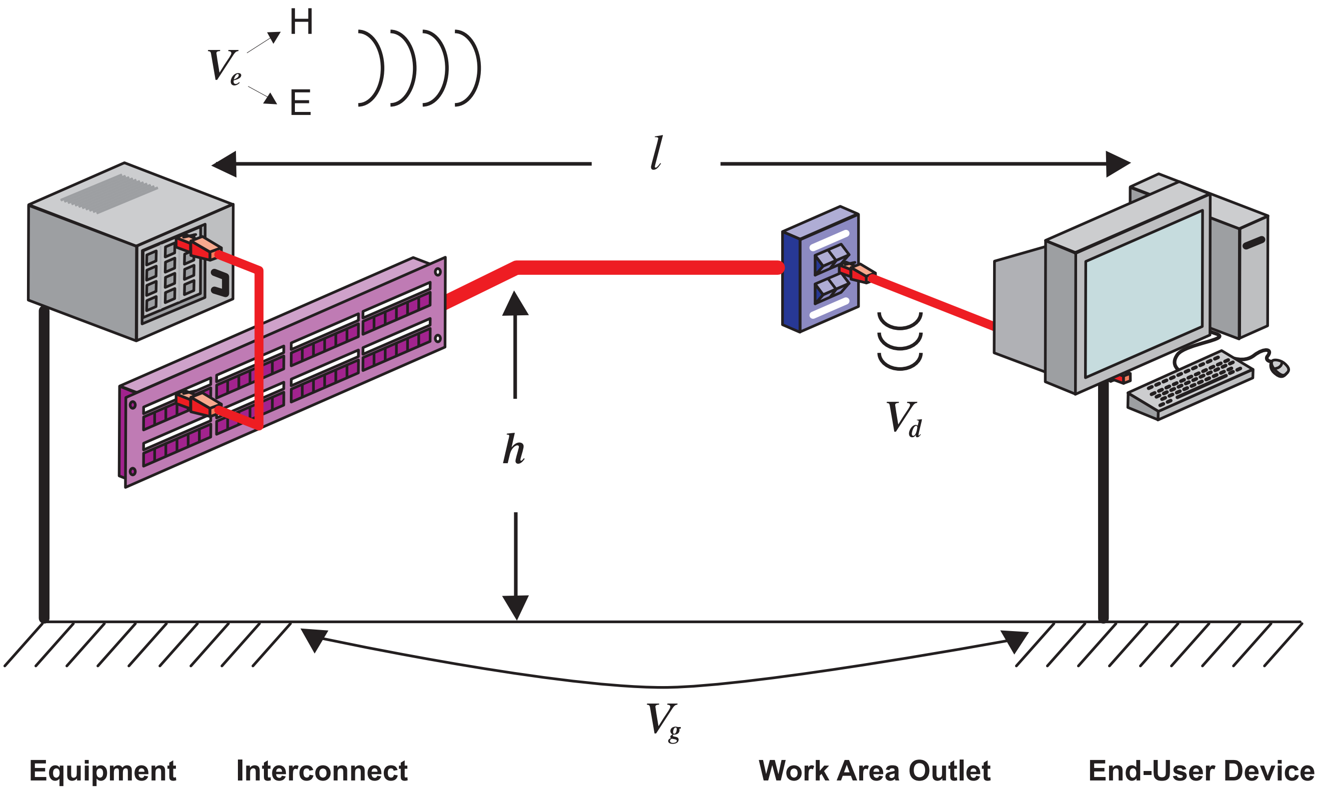
An effect of degraded twisted-pair signal balance above 30 MHz is modal conversion, which occurs when differential mode signals convert to common mode signals and vice versa. The conversion can adversely impact noise immunity from the environment, as well as contribute to crosstalk between pairs and balanced cables and must be minimized whenever possible. Shielding can decrease the potential for modal conversion by limiting noise coupled onto the twisted-pair from the environment.

CHAPTER 3: Fundamentals of Noise Interference

All applications require positive signal-to-noise (SNR) margins to transmit within allocated bit error rate (BER) levels. This means that the data signal being transmitted must be of greater magnitude than all of the combined noise disturbers coupled onto the transmission line (i.e. the structured cabling). As shown in figure 2, noise can be coupled onto twisted-pair cabling in any or all of three ways:

1. Differential noise (V_d): Noise induced from an adjacent twisted-pair or balanced cable
2. Environmental noise (V_e): Noise induced by an external electromagnetic field
3. Ground loop noise (V_g): Noise induced by a difference in potential between conductor ends

FIGURE 2: LAN NOISE SOURCES



Different applications have varying sensitivity to interference from these noise sources depending upon their capabilities. For example, the 10GBASE-T application is commonly recognized to be extremely sensitive to alien crosstalk (differential mode cable-to-cable coupling) because its digital signal processing (DSP) capability electronically cancels internal pair-to-pair crosstalk within each channel. Unlike pair-to-pair crosstalk, alien crosstalk cannot be cancelled by DSP. Conversely, since the magnitude of alien crosstalk is very small compared to the magnitude of pair-to-pair crosstalk, the presence of alien crosstalk minimally impacts the performance of other applications, such as 100BASE-T and 1000BASE-T that employ partial or no crosstalk cancelling algorithms.

Electromagnetic compatibility (EMC) describes both a system's susceptibility to interference from (immunity) and potential to disturb (emissions) outside sources and is an important indicator of a system's ability to co-exist with other electronic/electrical devices. Noise immunity and emissions performance is reciprocal, meaning that the cabling system's ability to maintain immunity to interference is proportional to the system's potential to radiate. Interestingly, while much unnecessary emphasis is placed on immunity considerations, it is an understood fact that structured cabling systems do not radiate or interfere with other equipment or systems in the telecommunications environment!

Differential noise disturbers: Alien crosstalk and internal pair-to-pair crosstalk are examples of differential mode noise disturbers that must be minimized through proper cabling system design. Susceptibility to interference from differential mode sources is dependent upon system balance and can be improved by isolating or separating conductors that are interfering with each other. Cabling with improved balance (i.e. category 6 and above) exhibits better internal crosstalk and alien crosstalk performance. Since no cable is perfectly balanced, strategies such as using dielectric material to separate conductors or using metal foil to isolate conductors are used to further improve crosstalk performance. For example, category 6A F/UTP cabling is proven to have substantially superior alien crosstalk performance than category 6A UTP cabling because its overall foil construction reduces alien crosstalk coupling to virtually zero. Category 7 S/FTP is proven to have substantially superior pair-to-pair and alien crosstalk performance than any category 6A cabling design because its individual foiled twisted-pair construction reduces pair-to-pair and alien crosstalk coupling to virtually zero. These superior crosstalk levels could not be achieved solely through compliant balance performance.

Environmental noise disturbers: Environmental noise is electromagnetic noise that is comprised of magnetic fields (H) generated by inductive coupling (expressed in A/m) and electric fields (E) generated by capacitive coupling (expressed in V/m). Magnetic field coupling occurs at low frequencies (i.e. 50Hz or 60 Hz) where the balance of the cabling system is more than sufficient to ensure immunity, which means that its impact can be ignored for all types of balanced cabling. Electric fields, however, can produce common mode voltages on balanced cables depending on their frequency. The magnitude of the voltage induced can be modeled assuming that the cabling system is susceptible to interference in the same manner as a loop antenna [1]. For ease of analysis, equation (1) represents a simplified loop antenna model that is appropriate for evaluating the impact on the electric field generated due to various interfering noise source bandwidths as well as the distance relationship of the twisted-pairs to the ground plane. Note that a more detailed model, which specially includes the incidence angle of the electric fields, is required to accurately calculate actual coupled noise voltage.

$$Ve = \frac{2\pi AE}{\lambda} \quad (1)$$

Where: λ is the wavelength of the interfering noise source

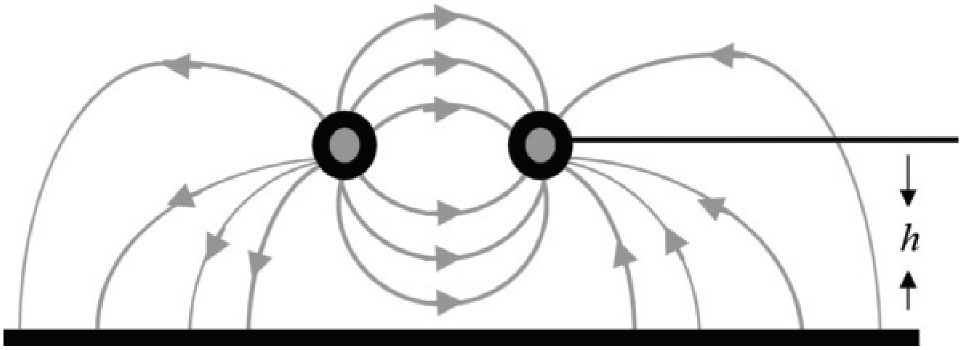
A = the area of the loop formed by the disturbed length of the cabling conductor (l) suspended an average height (h) above the ground plane

E = the electric field intensity of the interfering source

The wavelength, λ, of the interfering source can range anywhere from 5,000,000m for a 60 Hz signal to shorter than 1m for RF signals in the 100 MHz and higher band. The electric field strength density varies depending upon the disturber, is dependent upon proximity to the source, and is normally reduced to null levels at a distance of .3m from the source. The equation demonstrates that a 60 Hz signal results in an electric field disturbance that can only be measured in the thousandths of mV range, while sources operating in the MHz range can generate a fairly large electric field disturbance. For reference, 3V/m is considered to be a reasonable approximation of the average electric field present in a light industrial/commercial environment and 10V/m is considered to be a reasonable approximation of the average electric field present in an industrial environment.

The one variable that impacts the magnitude of the voltage coupled by the electric field is the loop area, A, that is calculated by multiplying the disturbed length of the cabling (**l**) by the average height (**h**) from the ground plane. The cross-sectional view in figure 3 depicts the common mode currents that are generated by an electric field. It is these currents that induce unwanted signals on the outermost conductive element of the cabling (i.e. the conductors themselves in a UTP environment or the overall screen/shield in a screened/fully-shielded environment). What becomes readily apparent is that the common mode impedance, as determined by the distance (**h**) to the ground plane, is not very well controlled in UTP environments. This impedance is dependent upon factors such as distance from metallic raceways, metallic structures surrounding the pairs, the use of non-metallic raceways, and termination location. Conversely, this common mode impedance is well defined and controlled in screened/fully-shielded cabling environments since the screen and/or shield acts as the ground plane. Average approximations for (**h**) can range anywhere from 0.1 to 1 meter for UTP cabling, but are significantly more constrained (i.e. less than 0.001m) for screened and fully-shielded cabling. This means that screened and fully-shielded cabling theoretically offers 100 to 1,000 times the immunity protection from electric field disturbances than UTP cabling does!

FIGURE 3: COMMON MODE CURRENTS

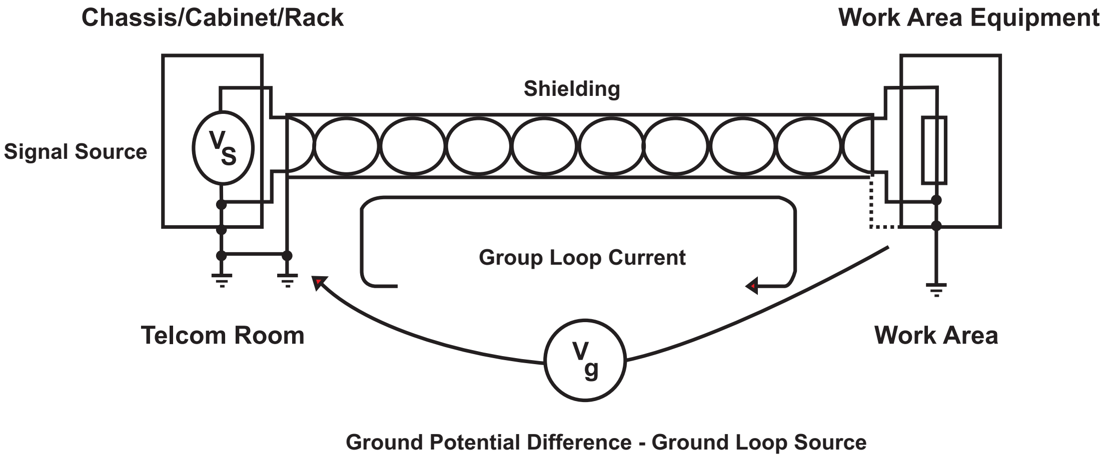


It is important to remember that the overall susceptibility of twisted-pair cables to electric field disturbance is dependent upon both the balance performance of the cabling and the presence of a screen or shield. Well balanced (i.e. category 6 and above) cables should be immune to electromagnetic interference up to 30 MHz. The presence of a shield or screen is necessary to avoid electromagnetic interference at higher frequencies, which is an especially critical consideration for next generation applications. For example, it is reasonable to model that an emerging application using DSP techniques will require a minimum SNR of 20 dB at 100MHz. Since the minimum isolation yielded by balance alone is also 20 dB at 100 MHz, the addition of a screen or shield is necessary to ensure that this application has sufficient noise immunity headroom for operation.

CHAPTER 4: Ground Loops

Ground loops develop when there is more than one ground connection and the difference in common mode voltage potential at these ground connections introduces (generates) noise on the cabling as shown in figure 4. It is a misconception that common mode noise from ground loops can only appear on screens and shields; this noise regularly appears on the twisted-pairs as well. One key point about the voltage generated by ground loops is that its waveform is directly related to the profile of the building AC power. In the US, the primary noise frequency is 60 Hz and its related harmonic, which is often referred to as AC "hum". In other regions of the world, the primary noise frequency is 50 Hz and its related harmonic.

FIGURE 4: INTRODUCTION OF GROUND LOOPS



Note: Shield grounded at the TR.
Note: At the WA there is a ground path to shield due to the equipment chassis or cabinet.

Since each twisted-pair is connected to a balun transformer and common mode noise rejection circuitry at both the NIC and network equipment ends, differences in the turns ratios and common mode ground impedances can result in common mode noise. The magnitude of the induced noise on the twisted-pairs can be reduced, but not eliminated, through the use of common mode terminations, chokes, and filters within the equipment.

Ground loops induced on the screen/shield typically occur because of a difference in potential between the ground connection at the telecommunications grounding busbar (TGB) and the building ground connection provided through the network equipment chassis at the work area end of the cabling. Note that it is not mandatory for equipment manufacturers to provide a low impedance building ground path from the shielded RJ45 jack through the equipment chassis. Sometimes the chassis is isolated from the building ground with a protective RC circuit and, in other cases, the shielded RJ45 jack is completely isolated from the chassis ground.

TIA and ISO standards identify the threshold when an excessive ground loop develops as when the difference in potential between the voltage measured at the shield at the work area end of the cabling and the voltage measured at the ground wire of the electrical outlet used to supply power to the workstation exceeds 1.0 Vrms. This difference in potential should be measured and corrected in the field to ensure proper network equipment operation, but values in excess of 1.0 Vrms are very rarely found in countries, such as the US, that have carefully designed and specified building and grounding systems. Furthermore, since the common mode voltage induced by ground loops is low frequency (i.e. 50 Hz or 60 Hz and their harmonic), the balance performance of the cabling plant by itself is sufficient to ensure immunity regardless of the actual voltage magnitude.

CHAPTER 5: Design of Screens and Shields

Shielding offers the benefits of significantly improved pair-to-pair crosstalk performance, alien crosstalk performance, and noise immunity that cannot be matched by any other cabling design strategy. Category 6A and lower rated F/UTP cables are constructed with an overall foil surrounding four twisted-pairs as shown in figure 5. Category 7 and higher rated S/FTP cables are constructed with an overall braid surrounding four individually foil shielded pairs as shown in figure 6. Optional drain wires are sometimes provided.

FIGURE 5: F/UTP CONSTRUCTION

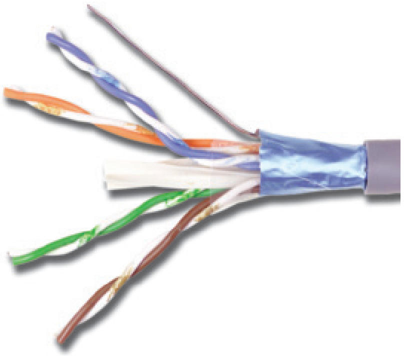


FIGURE 6: S/FTP CONSTRUCTION

Shielding materials are selected for their ability to maximize immunity to electric field disturbance by their capability to reflect the incoming wave, their absorption properties, and their ability to provide a low impedance signal path. As a rule, more conductive shielding materials yield greater amounts of incoming signal reflection. Solid aluminum foil is the preferred shielding media for telecommunications cabling because it provides 100% coverage against high frequency (i.e. greater than 100 MHz) leakage, as well as low electrical resistance when properly connected to ground. The thickness of the foil shield is influenced by the skin effect of the interfering noise currents. Skin effect is the phenomenon where the depth of penetration of the noise current decreases as frequency increases. Typical foil thicknesses are 1.5 mils (0.038mm) to 2.0 mils (0.051mm) to match the maximum penetration depth of a 30 MHz signal. This design approach ensures that higher frequency signals will not be able to pass through the foil shield. Lower frequency signals will not interfere with the twisted-pairs as a result of their good balance performance. Braids and drain wires add strength to cable assemblies and further decrease the end-to-end electrical resistance of the shield when the cabling system is properly connected to ground.

CHAPTER 6: Grounding and Cabling Systems

ANSI-J-STD-607-A-2002 defines the building telecommunications grounding and bonding infrastructure that originates at the service equipment (power) ground and extends throughout the building. It is important to recognize that the infrastructure applies to both UTP and screened/fully-shielded cabling systems. The Standard mandates that:

1. The telecommunications main grounding busbar (TMGB) is bonded to the main building service ground. Actual methods, materials and appropriate specifications for each of the components in the telecommunications grounding and bonding system vary according to system and network size, capacity and local codes.
2. If used, telecommunications grounding busbars (TGB's) are bonded to the TMGB via the telecommunications bonding backbone.
3. All racks and metallic pathways are connected to the TMGB or TGB.
4. The cabling plant and telecommunications equipment are grounded to equipment racks or adjacent metallic pathways.

TIA and ISO standards provide one additional step for the grounding of screened and shielded cabling systems. Specifically, clause 4.6 of ANSI/TIA-568-B.1 and clause 11.3 of ISO/IEC 11801:2002 state that the cable shield shall be bonded to the TGB in the telecommunications room and that grounding at the work area may be accomplished through the equipment power connection. This procedure is intended to support the optimum configuration of one ground connection to minimize the appearance of ground loops, but recognizes that multiple ground connections may be present along the cabling. Since the possibility that grounding at the work area through the equipment may occur was considered when the grounding and bonding recommendations specified in ANSI-J-STD-607-A-2002 were developed, there is no need to specifically avoid grounding the screened/shielded system at the end user's PC or device.

It is important to note the difference between a ground connection and a screen/shield connection. A ground connection bonds the screened/shielded cabling system to the TGB or TMGB, while a screened/shield connection maintains electrical continuation of the cable screen/shield through the screened/shielded telecommunication connectors along the full length of cabling. Part of the function of the screen or shield is to provide a low impedance ground path for noise currents that are induced on the shielding material. Compliance to the TIA and ISO specifications for the parameters of cable and connecting hardware transfer impedance and coupling attenuation ensures that a low impedance path is maintained through all screened/shielded connection points in the cabling system. For optimum alien crosstalk and noise immunity performance, shield continuity should be maintained throughout the end to end cabling system The use of UTP patch cords in screened/shielded cabling systems should be avoided.

It is suggested that building end-users perform a validation to ensure that screened and shielded cabling systems are properly ground to the TGB or TMGB. A recommended inspection plan is to:

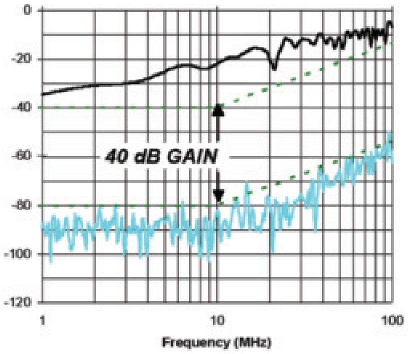
1. Visually inspect to verify that all equipment racks/cabinets/metallic pathways are bonded to the TGB or TGMB using a 6 AWG conductor.
2. Visually inspect to verify that all screened/shielded patch panels are bonded to the TGB or TGMB using a minimum of 12 AWG conductor, if not specified by the manufacturer instructions.
3. Perform a DC resistance test to ensure that each panel and rack/cabinet grounding connection exhibits a DC resistance measurement of <1 Ω between the bonding point of the panel/rack and the TGB or TMGB. (Note: some local/regional standards specify a maximum DC resistance of <5 Ω at this location.)
4. Document the visual inspection, DC test results, and all other applicable copper/fiber test results.

CHAPTER 7: The Antenna Myth

It is a common myth that screens and shields can behave as antennas because they are long lengths of metal. The fear is that screens and shields can "attract" signals that are in the environment or radiate signals that appear on the twisted-pairs. The fact is that both screens and shields and the copper balanced twisted-pairs in a UTP cable will behave as an antenna to some degree. The difference is that, as demonstrated by the simplified loop antenna model, the noise that couples onto the screen or shield is actually 100 to 1,000 times smaller in magnitude than the noise that is coupled onto an unshielded twisted-pair in the same environment. This is due to the internal pairs' well-defined and controlled common mode impedance to the ground plane that is provided by the screen/shield. Following is an analysis of the two types of signal disturbers that can affect the noise immunity performance of balanced twisted-pair cabling: those below 30 MHz and those above 30 MHz.

At frequencies below 30 MHz, noise currents from the environment can penetrate the screen/shield and affect the twisted-pairs. However, the simplified loop antenna model shows that the magnitude of these signals is substantially smaller (and mostly attenuated due to the absorption loss of the aluminum foil), meaning that unshielded twisted-pairs in the same environment are actually subjected to much a higher electric field strength. The good news is that the balance performance of the cable itself is sufficient up to 30 MHz to ensure minimum susceptibility to disturbance from these noise sources regardless of the presence of an overall screen/shield.

FIGURE 7:
UTP VS. F/UTP SUSCEPTIBILITY



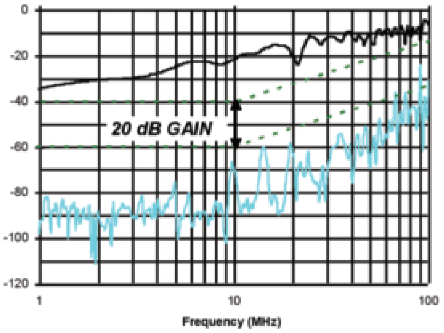
** Data provided courtesy of NEXANS/Berk-Tek*

At frequencies above 30 MHz, noise currents from the environment cannot penetrate the screen/shield due to skin effects and the internal twisted-pairs are fully immune to interference. Unfortunately, balance performance is no longer sufficient to ensure adequate noise immunity for UTP cabling at these higher frequencies. This can have an adverse impact on the cabling system's ability to maintain the SNR levels required by applications employing DSP technology.

The potential for a cable to behave as an antenna can be experimentally verified by arranging two balanced cables in series, injecting a signal into one cable to emulate a transmit antenna across a swept frequency range, and measuring the interference on an adjacent cable to emulate a receiving antenna[2]. As a rule of thumb: the higher the frequency of the noise source, the greater the potential for interference. As shown in figure 7, the coupling between two UTP cables (shown in black) is a minimum of 40 dB worse than the interaction between two properly grounded F/UTP cables (shown in blue). It should be noted that 40 dB of margin corresponds to 100 times less voltage coupling, thus confirming the modeled predictions. Clearly, the UTP cable is radiating and receiving (i.e. behaving like an antenna) substantially more than the F/UTP cable!

A second antenna myth is related to the inaccurate belief that common mode signals appearing on a screen or shield can only be dissipated through a low impedance ground path. The fear is that an ungrounded screen will radiate signals that are "bouncing back and forth" and "building up" over the screen/shield. The fact is that, left ungrounded, a screen/shield will still substantially attenuate higher frequency signals because of the low-pass filter formed by its resistance, distributed shunt capacitance, and series inductance. The effects of leaving both ends of a foil twisted-pair cable ungrounded can also be verified using the previous experimental method. As shown in figure 8, the coupling between two UTP cables (shown in black) is still a minimum of 20 dB worse than the interaction between two ungrounded F/UTP cables (shown in blue). It should be noted that 20 dB of margin corresponds to 10 times less voltage coupling. Even under worst-case, ungrounded conditions, the UTP cable behaves more like an antenna than the F/UTP cable!

**FIGURE 8:
UTP VS. UNGROUNDED F/UTP
SUSCEPTIBILITY**



** Data provided courtesy of NEXANS/Berk-Tek*

Modeled and experimental results clearly dispel the antenna myth. It is a fact that screens and shields offer substantially improved noise immunity compared to unshielded constructions above 30 MHz... even when improperly grounded.

CHAPTER 8: The Ground Loop Myth

It is a common myth that ground loops only appear on screened and shielded cabling systems. The fear is that ground loops resulting from a difference in voltage potential between a screen/shielded cabling system's ground connections cause excessive common mode currents that can adversely affect data transmission. The fact is that both screens and shields and the balanced twisted-pairs in a UTP cable are affected by differences in voltage potential at the ends of the channel.

The difference in the transformer common mode termination impedance at the NIC and the network equipment naturally results in common mode noise current being induced on each twisted-pair. Grounding of the screened/shielded system in multiple locations can also result in common mode noise current induced on the screen/shield. However, these common mode noise currents do not affect data transmission because, regardless of their voltage magnitude, their waveform is always associated with the profile of the building AC power (i.e. 50 Hz or 60 Hz). Due to the excellent balance of the cabling at low frequencies, common mode currents induced onto the twisted-pair either directly from equipment impedance differentials or coupled from a screen/shield are simply subtracted out by the transceiver as part of the differential transmission algorithm.

CHAPTER 9: Why use Screened/Fully-Shielded Cabling

The performance benefits of using screened and fully-shielded systems are numerous and include:

1. Reduced pair-to-pair crosstalk in fully-shielded designs
2. Reduced alien crosstalk in screened and fully-shielded designs
3. Screened category 6A cable diameters are generally smaller than 6A UTP cables allowing greater pathway fill/utilization
4. Substantially improved noise immunity at all frequencies and especially above 30 MHz when cable balance starts to significantly degrade
5. Significantly increased Shannon capacity for future applications

CONCLUSIONS

Achievable SNR margin is dependent upon the combined properties of cabling balance and the common mode and differential mode noise immunity provided by screens and shields. Applications rely on positive SNR margin to ensure proper signal transmission and minimum BER. With the emergence of 10GBASE-T, it's become clear that the noise isolation provided by good balance alone is just barely sufficient to support transmission objectives. The alien crosstalk and noise immunity benefits provided by F/UTP and S/FTP cabling designs have been demonstrated to offer almost double the Shannon capacity and this performance advantage has caught the attention of application developers and system specifiers. It's often said that the telecommunications industry has come full circle in the specification of its preferred media type. In actuality, today's screened and fully-shielded cabling systems represent a fusion of best features of the last two generations of LAN cabling: excellent balance to protect against low frequency interference and shielding to protect against high frequency interference.

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DEFINITIONS

absorption loss: Signal loss in a metallic media due to impedance losses and heating of the material
alien crosstalk: Undesired differential mode signal coupling between balanced twisted-pair cables
balance: The relationship between the differential signal and common mode signals on a twisted-pair
common mode: Signals that are in phase and are measured referenced to ground
differential mode: Signals that are 180° out of phase and measured referenced to each other
electromagnetic compatibility: The ability of a system to reject interference from noise sources (immunity) and operate without interfering with other devices or equipment (emissions)
equal level transverse conversion transfer loss: The ratio of the measured common mode voltage on a pair relative to a differential mode voltage applied on another pair and normalized to be independent of length
fully-shielded: A construction, applicable to category 7 and 7A cabling, where each twisted-pair is enclosed within an individual foil screen and the screened twisted-pairs are enclosed within an overall braid or foil
ground loop: A difference in voltage potential between two ground termination points that results in an induced common mode noise current
modal conversion: Undesired conversion of differential mode signal to common mode signal and vice versa that results from poor balance
screen: A metallic covering consisting of a longitudinally applied aluminum foil tape
screened: A construction, applicable to category 6A and lower-rated cabling, where an assembly of twisted-pairs is enclosed within an overall metal foil.
Shannon capacity model: A calculation to compute the maximum theoretical amount of error-free digital data that can be transmitted over an analog communications channel within a specified transmitter bandwidth and power spectrum and in the presence of known noise (Gaussian) interference
shield: A metallic covering consisting of an aluminum braid
shielded: See fully-shielded
transfer impedance: A measure of shield effectiveness
transverse conversion loss: The ratio of the measured common mode voltage on a pair relative to a differential mode voltage applied on the same pair
transverse conversion transfer loss: The ratio of the measured common mode voltage on a pair relative to a differential mode voltage applied on another pair

ACRONYMS

BER: Bit error rate
DSP: Digital signal processing
ELTCL: Equal level transverse conversion transfer loss
EMC: Electromagnetic compatibility
F/UTP: Foil unshielded twisted-pair (applicable to category 6A and lower-rated cabling)
IEEE: Institute of Electrical and Electronics Engineers
LAN: Local area network
NIC: Network interface card
S/FTP: Shielded foil twisted-pair (applicable to category 7 and 7A cabling)
SNR: Signal-to-noise margin
TCL: Transverse conversion loss
TGB: Telecommunications grounding busbar
TGMB: Telecommunications main grounding busbar
UTP: Unshielded twisted-pair (applicable to category 6A and lower-rated cabling)
Vrms: Volts, root mean square

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