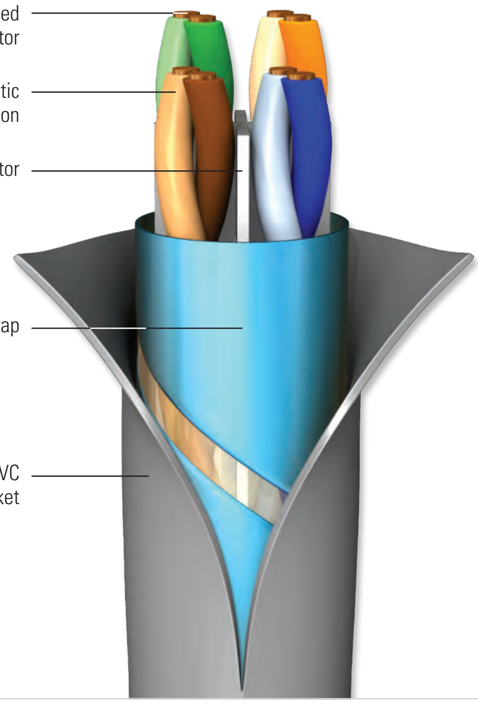
Noise Immunity of Next Generation Category 6A UTP Cables

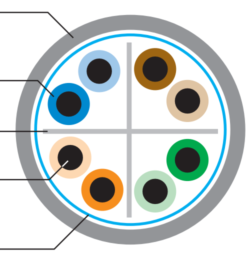
Extensive testing and analysis has been performed on the noise immunity characteristics of second generation Category 6A UTP cables designed with discontinuous metallic shield segments. The impact of external noise sources on this cable design is contrasted with the effects of alien crosstalk noise to determine if conditions or environments exist that could negatively impact system performance for 10GBase-T Ethernet networks.

Introduction

A few manufacturers, including Superior Essex, have developed Category 6A UTP cables that make use of the concept of discontinuous metallic shielding elements surrounding the inner 4-pair core of the cable. The effect of this approach is to attenuate both electromagnetic signals that emanate from the cable core and the potentially interfering electromagnetic signals that are generated by other sources. The metallic shielding elements are designed to be discontinuous to avoid any need for grounding, which is a requirement for shielded cable designs.

The concept of using discontinuous metallic shield elements within a Category 6A cable is quite novel to most engineers employed in the field of LAN cabling systems. Even though one would expect the shielding elements to provide some RF immunity benefits, it is not intuitive as to how a series of ungrounded “floating” shield elements would affect overall cable performance in the presence of high levels of unwanted electromagnetic interference (EMI).

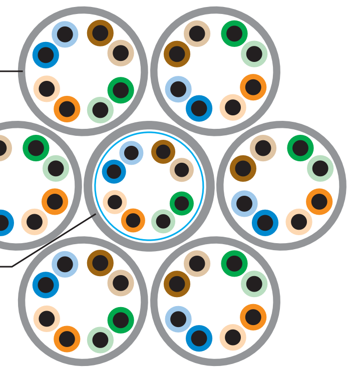




For this reason, Superior Essex has performed rigorous interference testing on its own Category 6A UTP cable made with discontinuous metallic shielding elements (trade name **10G**ain® **XP**). Claims of cable noise immunity made in this white paper are based on empirical results obtained through two different testing approaches performed at separate laboratories. The first set of tests utilized the industry standard Alien Crosstalk test method for Category 6A cables. The setup utilizes a “6-around-1” cable bundle to measure the crosstalk immunity of the center cable when six surrounding disturbing cables are used as interfering signal sources. Disturbing cables of the same type (as the center victim cable) and different type were tested.

The second test approach was performed at the Oklahoma State University Reverb Chamber Facility. The reverb chamber environment was used to create a uniform, controlled level of electromagnetic interference in the area occupied by the cable under test. The purpose of this test was to measure the effect of external (non-cable alien crosstalk) noise on the cable designed with discontinuous metallic shield elements (specifically, Superior Essex **10G**ain **XP** CAT 6A cable).

"Six-Around-One" Alien Crosstalk



Most LAN engineers are by now familiar with the six-around-one cable bundle Alien Crosstalk test method used to verify Category 6A UTP cable performance.

Alien Crosstalk performance of a Category 6A cable (or cabling system) is expressed by two measurements: (1) Power Sum Alien Crosstalk Near End Crosstalk (PSANEXT) and (2) Power Sum Alien Attenuation to Crosstalk Ratio Far End (PSAACRF). These two parameters provide a frequency dependent measure of the immunity of the center "victim" cable to interference created by six surrounding "disturbing" cables. Both of these electrical parameters are a critical measure of Category 6A cable (and system) performance because the digital signal processors (DSPs) used in 10GBase-T Ethernet electronics are not able to filter out high levels of noise generated by external sources.

"Six-around-one" Alien Crosstalk Test Results

In each of the tests described and depicted below, Superior Essex followed the industry accepted test procedure for 100 meter, 6-around-1 cable testing of Alien Crosstalk (PSANEXT and PSAACRF). The test procedure is specified in TIA 568-C.2.

TEST 1: Six Disturber Cables That are Identical to Center Victim Cable
Cable Sample A: Competitor Category 6A UTP Cable

Sample A is a competitive Category 6A UTP cable and was selected for the first test. This product is presently offered by a well known supplier/manufacturer of copper data cables in the U.S. Cable Sample A has a conventional design for Category 6A UTP cables. That is, it does not contain any metallic elements surrounding the core. Sample A cable also has an overall cable diameter of approximately 0.30 inches. Figures 1 and 2 show the measured PSANEXT and PSAACRF for Cable Sample A.

The marginal performance results depicted in Figures 1 and 2 are very typical of conventional designs for Category 6A UTP cables. The competing goals of small cable diameter and Alien Crosstalk immunity make it extremely difficult to obtain any significant Alien Crosstalk performance margin using a conventional design.

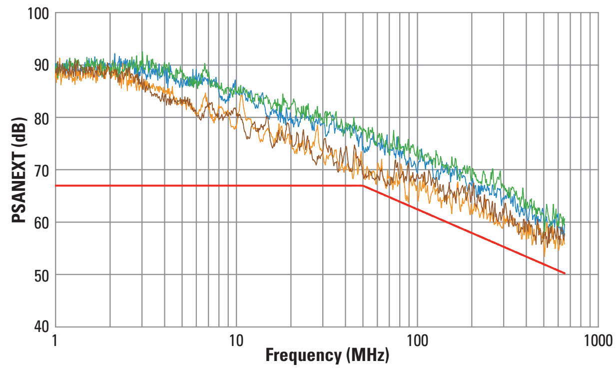


Figure 1: Cable Sample A: PSANEXT
Conventional CAT 6A UTP Cable

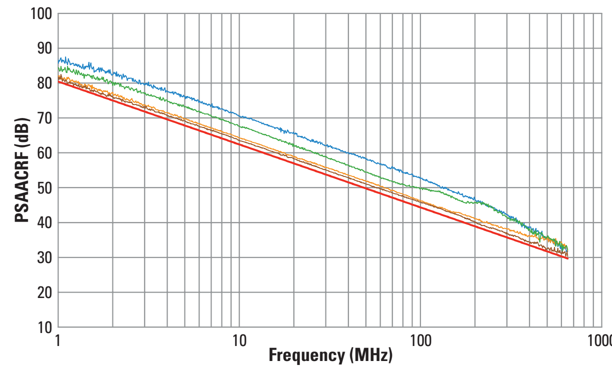


Figure 2: Cable Sample A: PSAACRF
Conventional CAT 6A UTP Cable

The marginal Alien Crosstalk performance of conventional Category 6A cables also makes them susceptible to electrical phasing effects, which are pronounced when the bunch lays of adjacent cables are aligned in-phase with the bunch lay of the cable under test.

TEST 1: Six Disturber Cables That are Identical to Center Victim Cable Cable Sample B: Category 6A Cable with Discontinuous Metallic Elements

Sample B is Superior Essex **10G**ain **XP** Category 6A UTP cable. This cable, as previously noted, uses a series of discontinuous metallic shielding elements to protect the core from unwanted interference. This design also has the effect of mitigating signals emanating from the cable itself. Sample B cable also has an overall cable diameter of approximately 0.30 inches – the same as the diameter of Sample A. Figures 3 and 4 show the measured PSANEXT and PSAACRF for Cable Sample B.

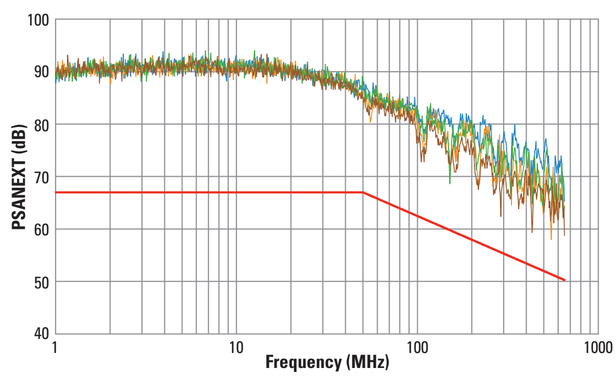


Figure 3: Cable Sample B: PSANEXT
10Gain **XP** CAT 6A UTP Cable

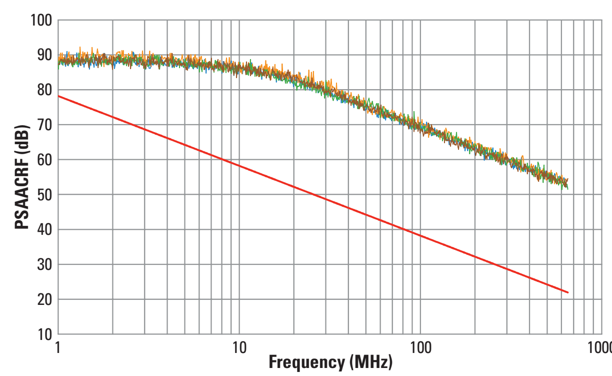


Figure 4: Cable Sample B: PSAACRF
10Gain **XP** CAT 6A UTP Cable

For Cable Sample B, the PSANEXT margin is approximately 6 dB at its worst point between 1 MHz and 500 MHz. The PSAACRF margin is approximately 11 dB at its worst point between 1 MHz and 500 MHz. These results are a significant contrast to the <1 dB margin provided by Cable Sample A for both PSANEXT and PSAACRF.

The superior noise mitigation performance of **10G**ain **XP** is largely attributed to the shielding effect of the discontinuous metallic elements surrounding the core. The gaps between segments of metallic elements within the **10G**ain **XP** cable occur at intervals over 1 meter. As a consequence, the probability of two gaps lining up at the same point between two adjacent cables is <0.1%. However, even if gaps were perfectly aligned between one cable and several other cables, the overall Alien Crosstalk performance would not be significantly degraded because <1% of the total surface area of the cable is not protected by a metallic element.

TEST 2: Six Category 5e UTP Disturber Cables Surrounding Center 10Gain XP Cat 6A UTP Cable

Disturber cables: Superior Essex Category 5e UTP Cables
Victim cable: Superior Essex **10G**ain **XP** Category 6A UTP Cable

Test 2 is a modification of the standard 6-around-1 Alien Crosstalk industry test. The purpose of using Category 5e cables as the “disturber” cables is to verify that the apparent noise immunity of the **10G**ain **XP** cable, as measured in Test 1, is still adequate when the disturber cables are not protected by discontinuous metallic elements surrounding the cable core. Category 5e cables were specifically chosen because they typically have the smallest diameter of any copper data cable used in a LAN, which means the center of the disturber cables will be as close to the victim cable as possible for a typical commercial application.

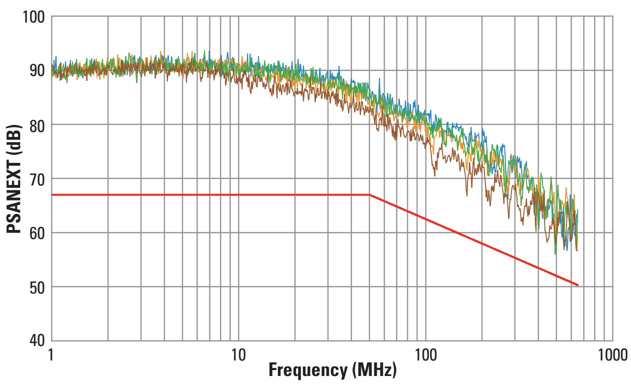


Figure 5: PSANEXT: CAT 5e cables as disturbers to **10G**ain **XP** CAT 6A UTP Cable

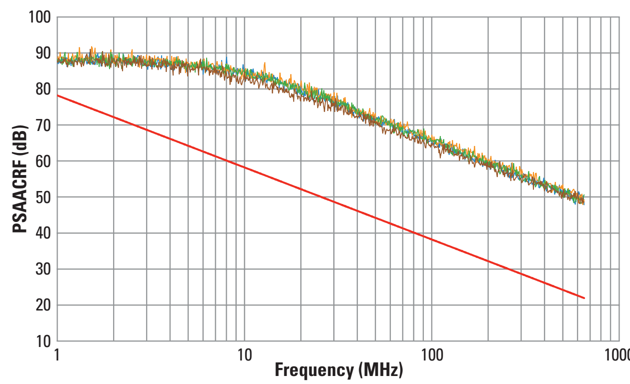


Figure 6: PSAACRF: CAT 5e cables as disturbers to **10G**ain **XP** CAT 6A UTP Cable

Comparing Figures 5 and 6 to Figures 3 and 4 respectively, it is apparent that the Alien Crosstalk margin decreased approximately 2 dB when the disturber cables were switched from **10G**ain **XP** CAT 6A UTP to Category 5e. However, the Alien Crosstalk measurements of the victim cable in the second test still exceeded the industry requirements by considerable margin.

Reverb Chamber Tests

To test the effects of unwanted electromagnetic interference of external sources on **10G**ain **XP** Category 6A cable, Superior Essex conducted tests at the Oklahoma State University (OSU) Reverb Chamber Facility.

Description of Reverb Chamber Facility and Test Set-up

The OSU reverb chamber is a "Smart 80" type design. This designation indicates that chambers of such design are useful for frequencies as low as 80 MHz. The dimensions of this particular chamber are 44' L x 19' W x 17' H. The chamber has an inner surface consisting of galvanized steel on the walls, the ceiling and the floor. A vertical "tuner,' or mode stirrer, was used to broadcast the interfering signals at 50 different rotational positions. The signal levels in the chamber were measured by a network analyzer and E-field probe, with a sample rate of one per second.

100 meters of **10G**ain **XP** cable was laid on a surface about 3 feet wide and 20 feet long (traversed 8 times) and 4 feet above the floor using Styrofoam blocks. About 30 feet of cable was used to extend the test end on the table-like surface through the wall into the measurement room.

Terminations were applied to both ends on the 4 pairs. Each pair was terminated in both differential and common mode. Each termination consisted of two 50 Ohm resistors connecting the individual wires to common. The resultant differential termination was 100 Ohms. Each of the 4 pairs (1 pair per test) was connected to a 50 to 100 Ohm balun, which in turn was connected to the receive port of the network analyzer.

As part of the measurement procedure, a 1601 linear frequency network analyzer transfer function trace was taken for each of the 50 tuner positions for the frequency range 100 MHz to 750 MHz.

Figure 7: Reverb chamber with rotating vertical tuner and cable under test

Interference Levels

The measured electric field intensity in the chamber was an average of 7.4 volt/meter, based on the vector sum of the x, y, and z components. This average field strength was chosen because it represents a level of received power that would be considered extremely high in a LAN environment. Figure 8 compares the electric field intensity measured in our reverb chamber test against the expected measured electric field intensity generated by potential interference sources transmitting in the 1-500 MHz band – the operating frequency range for 10GBase-T networks. The hypothetical interference sources in this comparison include:

1. A VHF TV station broadcasting 1 million watts ERP (Effective Radiated Power), 1 km away (from the cable), in the operating range of 54 MHz to 216 MHz
2. RF noise transmitted by 100 separate switches/servers located an average of 25 ft away (from the cable); all hypothetical devices are transmitting RF noise up to the maximum allowed by FCC part 15
3. A handheld mobile radio, transmitting at 3 watts and located an average of 3 meters away (from the cable)

Figure 8 shows that the voltage levels measured within the reverb chamber were higher, but comparable to the worst of the three hypothetical interference situations. However, it is important to note that the 3-watt mobile radio scenario would not create the interference levels shown in Figure 8 for the entire length of installed cable because received power is inversely proportional to distance squared from the transmitter. Consequently, interference received on the cable from a mobile radio would rapidly diminish as the cable traverses away from the radio.

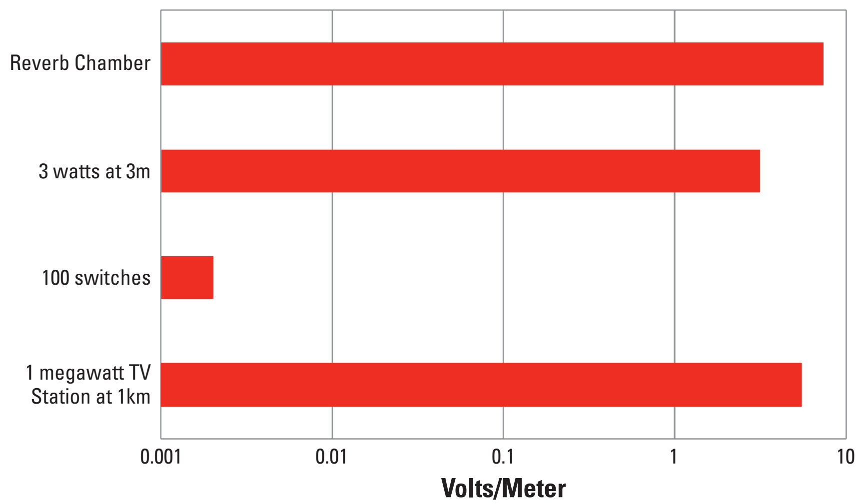


Figure 8: Comparison of voltage levels – reverb chamber and other hypothetical interference scenarios

Reverb Chamber Test Results

Figure 9 shows the average power level measured on each of the 4 pairs of the **10G**ain **XP** Category 6A cable under test within the reverb chamber. In this graph, the values represent an average of the measurements taken for the 50 vertical tuner positions. The results are shown in dBm units. For reference, 0 dBm is equal to 1 milliwatt. As one notices from Figure 9, the power measured on the cable was relatively consistent across the frequency band, with an average of approximately -80 dBm.

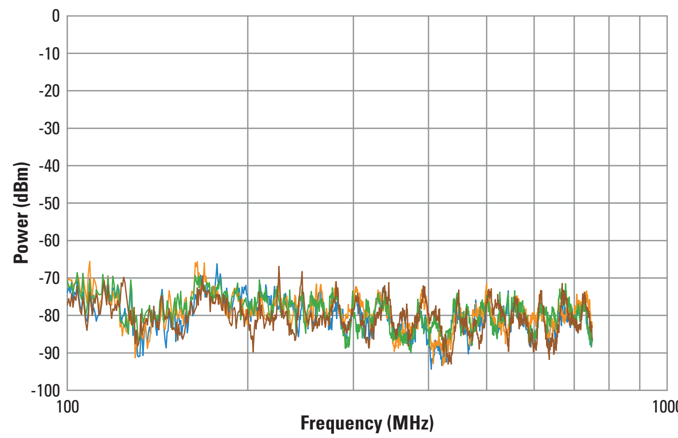


*Figure 9: Measured power levels on **10G**ain **XP** cable in reverb chamber*

In order to draw conclusions from the values shown in Figure 9, we need a reference point for levels of interference on a Category 6A cable that are considered unacceptable. Fortunately, the TIA 568-C.2 and IEEE 802.3an standards provide such a reference through the specifications for maximum Alien Crosstalk signal levels. It is worthwhile to point out that an interfering signal from a source such as a TV transmitter is considered 'far field,' in which the field strength scales inversely with distance. In contrast, cable Alien Crosstalk is considered 'near field' and the field strength scales inversely with distance squared. The effects of 'far field' and 'near field' also have different frequency dependencies. Nonetheless, it is valid to compare these two types of interference on an absolute noise basis.

Figure 10 shows the TIA 568-C.2 PSANEXT specification limit line, expressed in dBm, in comparison to the actual power measurements taken in the reverb chamber for each of the 4 pairs.

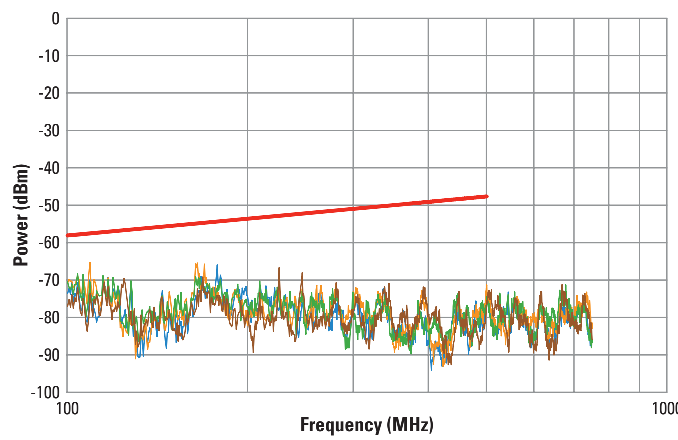


*Figure 10: Measured power levels on **10G**ain **XP** cable in reverb chamber vs. Alien Crosstalk limit line*

At its closest point to the Alien Crosstalk limit, the power level measured on the worst pair of the CAT 6A cable was 9 dB lower. On average, the power measured on the **10G**ain **XP** CAT 6A pairs was approximately 20 dB lower than the Alien Crosstalk limit line. From this observation we can make the following conclusions:

1. Cables designed with discontinuous metallic elements surrounding the core, specifically the 10Gain XP cable, provide more than sufficient immunity to external RF interference, even in environments where extremely high powered RF transmitters are in close proximity.
2. Alien Crosstalk from adjacent disturber cables will create much more potential interference for Category 6A cables than external sources of interference. In a typical environment (i.e., without a nearby TV broadcast tower), sources of external interference will be 40 dB or more below the Alien Crosstalk limit line.

Out of Band Interferers (> 500 MHz)

Out of band interference (> 500 MHz signals) is also a possibility in any LAN environment. Potential interferers include Wi-Fi transmitters, microwave signals, and cell site transmitters. Out of band signals that find their way onto the Category 6A cable, however, should not pose any problem for 10GBase-T applications, as several forms of immunity to block out of band interference are present in 10GBase-T networks.

1. 10GBase-T PHY (physical layer) devices contain filtering elements that sharply attenuate signals above 500 MHz.
2. Interference occurs on twisted pairs in common mode (as opposed to differential mode). Common mode rejection is a property of baluns, which are present in 10GBase-T PHY devices.
3. Twisted pair cables typically attenuate signals according to the formula $2\sqrt{f}$ dB/100 m, where f = MHz. Consequently, high frequency interference signals typically need to occur on the cable in close proximity to the receiver for there to be any potential for receiver interference. Unwanted high frequency signals occurring on distant portions of the cable will be severely attenuated prior to reaching the receiver.

Effects of Spurious Signal Interference from Intermodulation Sources

Intermodulation interference is the undesired combining of several signals in a nonlinear device to produce undesired frequencies that can cause interference in adjacent receivers. By design, UTP cabling does not create intermodulation interference, but if such signals were being transmitted by another non-linear device, the unwanted frequencies could couple onto one or more twisted pairs and be carried to the receiver. Spurious signals created by intermodulation are always attenuated from the carrier signal level of the originating transmitter. As we have shown above, **10G**ain **XP** Category 6A cable provides excellent immunity against unwanted carrier signals in the 100 to 750 MHz frequency range. It is highly improbable that spurious signals resulting from intermodulation interference would ever reach power levels in the area that would in turn be insufficiently blocked by 10Gain XP CAT 6A cable such that the interference measured on the cable would exceed the defined Alien Crosstalk limit (approximately -62 dBm to -52 dBm between 100 MHz and 500 MHz) for Category 6A UTP cables.

Summary and Conclusion

Category 6A UTP cables designed with discontinuous metallic shielding elements surrounding the core have been shown to provide superior Alien Crosstalk performance in comparison to conventionally designed Category 6A UTP cables. For the samples tested by Superior Essex and detailed in this paper, the difference was 6 dB for PSANEXT and 11 dB for PSAACRF.

Category 6A UTP cables designed with discontinuous metallic shielding elements, specifically Superior Essex 10Gain XP CAT 6A cable, also provide substantial protection against the Alien Crosstalk effects of Category 5e cables in a 6-around-1 bundle scenario.

Typical sources of external interference in a cabled environment (e.g., EMI generated from active devices) will create noise levels on 10Gain XP CAT 6A cable that are 40 dB or more below the TIA 568-C.2 Alien Crosstalk limit line.

Extreme levels of external interference in a cabled environment (e.g., 1-Megawatt TV Station within 1 km) will create noise levels that can be measured on 10Gain XP CAT 6A cable, but these levels are 9 to 20 dB below the TIA 568-C.2 Alien Crosstalk power requirements.

It is conclusive from the tests and results presented in this paper that Alien Crosstalk interference from nearby Category cables represents the greatest threat of interference to a 10GBase-T Ethernet network. Interference from other external sources is significantly weaker and sufficiently blocked by the tightly twisted pairs that are common among all Category 6A cables. An engineer who is concerned about the effect of interference on his cable plant should use Alien Crosstalk performance as the gating factor for cabling system selection.