White Paper

Accelerated degradation of balanced twisted pair performance due to the use of remote powering (PoE+)

excel
without compromise.

Overview

It had been observed during testing carried out in conjunction with De Montfort University in 2014 that heating due to remote powering over twisted pair cables appears to degrade the cable performance. With power heading towards 100W, this could be significant. In fact we even witnessed failure within the cable bundles when thermally insulated and operating at this high power and hence temperature, this was presented in the Proceedings of IWCS 2014.

In this present study, we assessed the performance degradation of balanced twisted pair cable by repeated heating cycles for both temperatures within the standards specification and beyond. It was suspected that repeated heat cycles would lead to accelerated ageing of the compounds used for the dielectric insulating materials around the conductors, which in turn would lead to changes in the performance values of the cables when tested.

Part of these assumptions were based upon work being carried out by SPIE the Specialist Plastics Industry group who are looking to launch similar research in conjunction with UL (Underwriters Laboratory) after they had related concerns regarding the performance of the cladding materials used in fibre cables.

The tests in the study thermally cycle the cable from an ambient of +20 degrees up to an ambient of +70 degrees to see if there is any substantial 'knee point' in behaviour. Also, to assess the performance degradation at elevated temperature, the thermal cycling was extended to about 120°C.

Background of Study

The specification of the IEEE 802.3at includes 60°C as the maximum acceptable operating environment for cabling supporting PoE+. However, the Addendum TIA TSB-184 specified 15°C as the maximum allowable temperature rise above ambient for any cable rated for 60°C. This means, no matter how much power is being pushed down the cable, the number of cables deployed per bundle, the cable type and the installation condition, temperature rise above 45°C for instance, will have to stay within the 15°C limit.

This specification remains a challenge for the Unscreened Twisted Pair (U/UTP) cables, specifically once installed in a restricted heat dissipation environment. This is because the lower categories of cable have smaller conductor sizes and their D.C loop resistance per unit length is higher than that of the higher categories of cable. Category 6_A has a larger cable diameter than the lower categories of cable and therefore does not heat up as much.

In a typical installation where cables exist in a number of bundles and are packed together, they will also possibly experience proximity of heat sources and that could lead to an excessive temperature rise within the cable itself and the surrounding cables. This has been suggested by SPIE as a contributing factor to heat-aging of the cable polymers and the potential performance degradation of the cabling system. Additionally, communication cables may be subjected to different operating and environmental conditions that can also alter their performance.

A study conducted near a return air plenum during the summer period suggested a peak temperature of 40°C. Cables installed in such areas may experience change in temperature that may lead to the modification of the cable properties and could cause attenuation issues in transmission, leading to increased signal attenuation and high bit error rate in some applications.

Experiment Description

The experiment into accelerated age testing was performed on a Category 6 U/UTP cable link. As shown in figure 5 below, the laboratory set up consists of a DSX-5000 Cable Analyzer, kindly supplied to the University by Fluke Networks, with the appropriate permanent link adapters, a set of thermocouple sensors of K type, a wire basket tray, a temperature data logger for the automatic temperature readings from the thermocouple sensors, some heating elements for the purpose of heating the cable externally, Power Supply Units (PSU) that were used for powering the heating elements, a constructed heat chamber and a 50m length of Category 6 U/UTP that was subjected to thermal degradation inside the constructed heat chamber.

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Figure 5

The heat chamber is about 2m length and was constructed using a wooden box with a lid. The internal surface of the chamber was lined with an insulating foil. The wire basket tray was raised off the bottom of the box. The heat chamber had two openings on its sides. One opening was used to place the thermocouple sensors on different positions on the cable, while the other opening was used for the mounting of a faceplate that was housing the Category 6 keystone jacks.

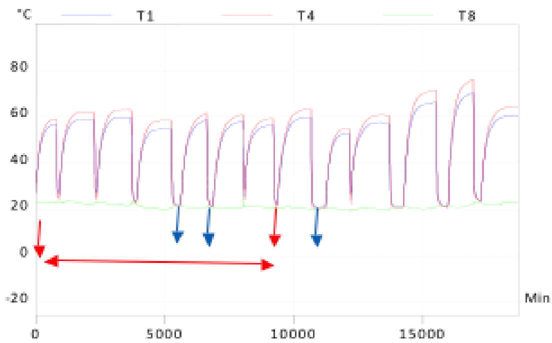
The tests were performed using the upper operating temperature specified within ISO/11801 of 60°C and were later increased to 80°C in order to observe the behaviour of the cable when operating at a temperature above the specified limit. The Category 6 cable sample was spooled loosely and on the wire basket tray and thermocouple sensors were placed in various locations of the cable jacketing material. The cable was kept at a permanent position, inside the heat chamber and without any movement throughout the test period. The measurement ends of the cable were terminated with standard Category 6 keystone jacks.

Before the test began, the main and the remote ends of the Cable Analyzer were connected using the Permanent Link Adaptors. ISO/IEC 11801 Class E test limit was selected on the Cable Analyzer, along with the correct cable type and Nominal Velocity of Propagation (NVP) value was set.

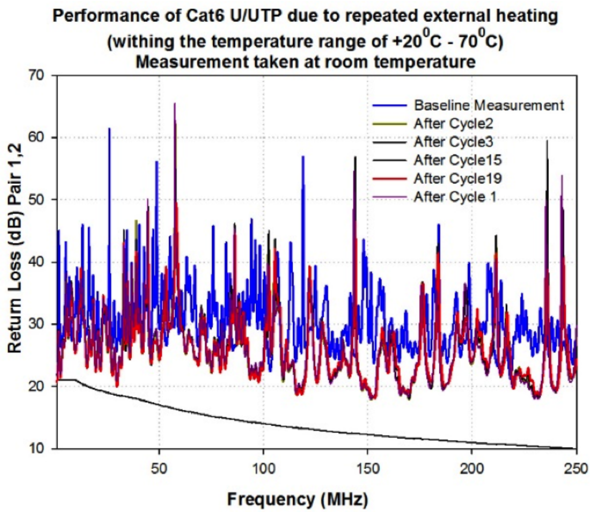
To establish a baseline cable performance and to verify the cable compliance with the ISO1811 class E standard limit, the permanent link adapters were attached to the outlets at the outside of the heat chamber and the certification tests were performed. The measurements taken at an ambient temperature of 23°C before the test began passed the certification tests.

Also, before the heating cycling began, the thermocouples placed on the various locations of the cable were connected to a data logger that allowed the temperature readings to be recorded automatically. During the first heating cycle, the cable sample was tested at an ambient temperature of 20°C. When the temperature on the cable under test had risen to about 10°C, measurements were taken again. For this initial experiment, 25 consecutive heating measurements were made with an increment of 10°C, up to a maximum operating temperature of 70°C. When the temperature on the cable had reached ~70°C, the cable was allowed to cool naturally by turning off the heat source and by taking the heat chamber lid off. The second heating cycle started when the temperature on the cable was at or near room temperature. This process was repeated for 10 heating cycles. After a trend in the cable performance had been observed for 10 heating cycles, another 2 heating cycles (cycle 11 and cycle 12) were carried out using the previous process but with a prolonged heating time.

To gain sufficient information in order to predict the effects of the repeated heating cycles on the cable performance, another 13 heating cycles were carried out. The temperature profile for the last 13 heating cycles is shown in the following.



Return loss has been used in this paper as a good illustration of the cable performance and the following figure shows the Return Loss for several of the heating cycles. It is interesting to observe that the first cycle of heating brought about changes to the overall profile which did not change for the other cycles.



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In the previous study in 2014, the catastrophic effects associated with energizing U/UTP cable bundles with 100W were reported.

Similarly, a recent study on the performance of the U/UTP cables has reported high attenuation at elevated temperature. As a result of this, the performance of the U/UTP cables poses a great concern under extreme conditions.

Conclusion and Recommendation

Remote powering is a fact of networked life, aging and degradation is to be expected during remote powering. It can be minimized by avoiding extreme temperatures or by 'running in' the cables by powering them up to get them hot prior to installation (pre-aging) and then rechecking that they still meet specifications. There are two key aspects that this paper impacts. The first is the physical behaviour of the cabling and the second is the implications that this has on the integration of cabling within the building design.

While the reason for changes in the cable data is not specifically understood, some polymer degradation effect is likely, however further research to look at complex permittivity assessment of the dielectrics on their own and as part of transmission will be needed into the physical or chemical changes within the dielectrics.

The second aspect that comes out of this work is associated with integrated building design. As data services in 'smart' buildings become more fundamental to the operation and management of the building, health monitoring and management of the data infrastructure becomes vital to ensuring that other services and operations of the building do not become impaired. This paper has looked at the effects of repeated and extended heating of Ethernet cables. It has demonstrated that while changes to the performance within the 'usual' range of temperatures can cause changes to the performance profile, these are generally within specification. However, should the temperature extend beyond this, the safety margin is not terribly large, with only something like 30 degrees of headroom. This, in itself should be sufficient for most operations. However, consider a bundle of cables remote powering end equipment and passing through a roof space in a non-air-conditioned building: a bundle core temperature exceeding 100°C may be a possibility. So, what is the implication of this? It is typical that new buildings will be modelled for air-flow, insulation and temperature (for the comfort of those who use the building). The conclusion from this paper is that the simulation also needs to include data cable pathway temperature simulation, which includes potential self-heating effects and those areas with greatest risk of excess heating are monitored and the temperature controlled with the same attention that the equipment at either end of the cable is thermally managed.

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