University of Oxford IT Services
Infrastructure Installation Specification Strategy

IISS-01-001:
Assessment of balanced cabling test results

1 INTRODUCTION

1.1 Scope

The increasing availability of non-standard cable products such as “copper coated aluminium” and “copper coated steel” together with that of partially[a] standards-compliant products such as so-called “zone cables” both produce performance levels that are higher than those specified for certain length-dependent parameters – in particular, attenuation/insertion loss and d.c. loop resistance.

Cables with high levels of d.c. loop resistance represent a cause for concern when allied to the rapid increase in the number of applications operating using remote powering - where the telecommunications cables provide the distribution of power using Power over Ethernet and other solutions. The Infrastructure Installation Specification Strategy: Overview document, IISS-00-001, produced by University of Oxford IT Services has been updated, coincident with this document, to highlight the risks associated with the delivery of remote powering and the impact of high resistance cables on those risks (in addition to other long-term cost of ownership issues).

This document describes how to assess balanced cabling test results to identify where such cables may be present. It also provides some advice on inspection of cables both prior to installation and during operation.

[a] meaning that the products comply with a quoted cable standard but are being used in a manner not intended by the cabling standards.

1.2 Background to testing of balanced cabling

Testing of balanced cabling link and channels (see Figure 1) may be undertaken against the requirements of a Class (e.g. D, E, E_A, F or F_A) of the BS EN 50173 series of standards or a Category (e.g. 5e, 6 or 6A) of the ANSI/TIA-568-2.D standard.

NOTE Class I and Class II cabling is not addressed in this document due their short installed length but this document also applies to these implementations.

NOTE ISO/IEC 11801 series standards also specify installed cabling in terms of Class.

In either case, the test produces results for a considerable number of parameters some of which are considered the basis of a “pass” or “fail” both as an individual parameter but also of the overall group.

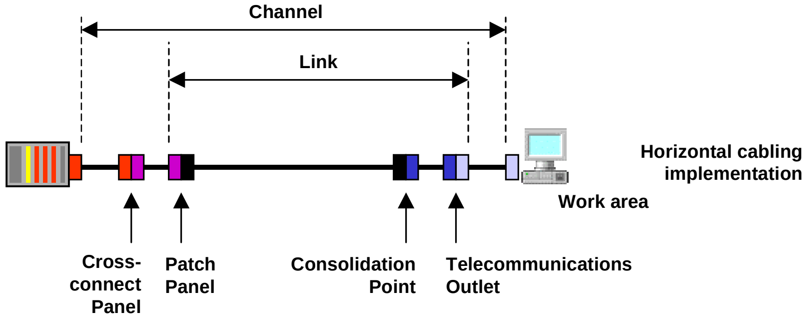

Figure 1 - Transmission links and channels

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The requirements against which these parameters are tested can be classified as either length-independent or length-dependent - the latter meaning that the calculations that produce the requirements of the standard contain a “length factor”. Table 1 provides a summary of the parameters that are typically measured and which of them are considered length dependent.

Table 1 makes certain facts immediately obvious:

- the requirements for all parameters associated with cabling channels (end-to-end connections) are never length-dependent since they are defined to provide the necessary performance to support the application delivered by the attached equipment - channel performance for all parameters is defined in terms of pass or fail against a single limit (which may be frequency dependent but not length dependent);
- the requirements for some parameters of cabling links (i.e. parts of a channel) in accordance with BS EN 50173 and ISO/IEC 11801 series standards are length-dependent as shown in the highlighted box in Table 1;
- the ANSI/TIA standards contain no length-based calculations of the requirements for parameters of cabling links - although they do provide the base information to generate them.

Table 1 - Parametric requirements for installed balanced cabling

Standards	Parameter	Link	Channel
BS EN 50173-1 and ISO/IEC 11801-1	Attenuation/Insertion loss	Length-dependent	Length-independent
	Propagation delay		
	Delay skew		
	d.c. loop resistance		
	Return loss	Length-independent	
	NEXT/PSNEXT		
	ACR-F/PSACR-F		
ANSI/TIA-568-2.D	Attenuation/Insertion loss		
	Propagation delay		
	Delay skew		
	d.c. loop resistance		
	Return loss		
	NEXT/PSNEXT		
	ACR-F/PSACR-F		

It is important to differentiate between requirements and limits. All the standards contain limits (i.e. worst case allowed values) for the parameters of cabling links. These limits are based upon maximum lengths and number of connections and it is these figures that are generally used by the software within test equipment to adjudicate PASS/FAIL status of the result for each parameter. However, only the BS EN and ISO/IEC standards define requirements which generate different limits based on the length of the link – but these length-dependent limits are rarely, if ever, implemented in the test equipment.

Test equipment used to assess compliance with the cabling standard of BS EN 50173 series, ISO/IEC 11801 series and ANSI/TIA-568 standards is required to meet specific European, international and North American standards as shown in Table 2.

Table 2 - Test equipment standards

Cabling	Test equipment standard		
BS EN, ISO/IEC -- ANSI/TIA	**European**	**International**	**North American**
	EN 61935-1	IEC 61935-1	ANSI/TIA-1152
Class D -- Category 5e	Level IIE - Level V		
Class E -- Category 6	Level III - Level V		
Class E_A -- Category 6A	Level IIIE - Level V		
Class F and F_A	Level IV or Level V		Not specified
Class F_A	Level V		Not specified

Historically, there has been no real problem resulting from test equipment not applying the true length-dependent limits required by the BS EN and ISO/IEC cabling Class requirements.

However, the growing availability of non-standard cable products such as “copper coated aluminium” and “copper coated steel” together with the partially standards-compliant products such as so-called “zone cables” both produce higher than allowed length-dependent parameters - specifically attenuation/insertion loss and d.c. loop resistance. The failure to measure and report against length-dependent limits is now becoming an issue of importance. To make matters worse, the ANSI/TIA-1152 standard does not call for failing d.c. loop resistance results to be recorded as such on test records - even though ANSI/TIA-568-2.D states a limit.

An example of this concern is shown in Figure 2. This shows a link of length 63 metres with a d.c. loop resistance of more than 50 Ω. The value at that length should not exceed 14,5 Ω and therefore this cable will dissipate more than three times as much heat per unit length than expected when subjected to a Power over Ethernet type delivery of remote powering.

```
Cable ID: NY09 Bad Return Loss                   Test Summary:FAIL
Project: New Project                             Headroom: 7.0 dB (NEXT @ Remote 36-78)
Date / Time: 11/15/2009 06:51:21am               Test Limit: TIA Cat 5e Perm. Link
OPERATOR:                                        Cable Type: Cat 5e UTP
Software Version: 2.1200                         DTX-1800     S/N: 8582252 DTX-CHA001
NVP: 69.0%                                       DTX-1800R    S/N: 8692096 DTX-CHA001
                                                 Limits Version: 1.3600

Wire Map: PASS                  Result    RJ45 PIN:       1 2 3 4 5 6 7 8
(T568B)                                                   | | | | | | | |
                                          RJ45 PIN:       1 2 3 4 5 6 7 8
     |Length        |Prop.       |Delay      |Resistance  |Impedance   |Insertion Loss       |
     |              |Delay       |Skew       |            |            |Result  Freq.  Limit|
Pair |(m)     Limit |ns    Limit |ns   Limit |ohms  Limit |ohms Limit  | (dB)    MHz    (dB)|
12   |63.9    90.0  |309     498 |6       44 |54.8        |            | -2.3 F  52.8   14.8 |
36   |63.5    90.0  |307     498 |4       44 |53.2        |            | -0.5 F  54.8   15.1 |
45   |63.1    90.0  |305     498 |2       44 |51.2        |            | -0.3 F   4.0    3.9 |
78   |62.7    90.0  |303     498 |0       44 |52.9        |            | -0.4 F  11.1    6.5 |
```

Figure 2 – Example of high D.C. loop resistance

The test result of Figure 2 only came to the installers attention because of the attenuation/insertion loss of the cabling was marginally too high - which itself is a major problem for a link only 63 metres long but has no thermal impact – which cause the overall test to be recorded as a “FAIL”. The link has been measured against the Category 5e specification using equipment in accordance with ANSI/TIA-1152 and the test system, as stated above, shows no limit for d.c. resistance and therefore the test equipment/result did not record a “FAIL”, or even highlight, this potentially serious problem for that parameter. This is an extreme condition and in reality many copper coated aluminium cables feature resistance values only 40-70 % higher than the expected values rather than the > 300 % level shown in Figure 2.

2 LENGTH-DEPENDENCY

BS EN 50173-1 and ISO/IEC 11801-1 standards provide formulas for the calculation of the requirements. These are of the form shown in Table 3.

Table 3 – Form of length-dependent formulae

Parameter	Typical formula
Attenuation/insertion loss (dB)	L/100 x $\text{cable}_{\text{Category n}}$ (100m) + n x $\text{connections}_{\text{Category n}}$
Propagation delay (µs)	L/100 x cable (100m) + n x connections
Delay skew (ns)	L/100 x $\text{cable}_{\text{Category n}}$ (100m) + n x connections
d.c. loop resistance (Ω)	L/100 x 22 + n x 0,4
The term “Category n“ indicates that the values are dependent on the Category of the components used.	

These formulae produce the values shown in Table 4 which shows the calculated values for different link lengths together with the “one-stop” simplified limits used by the test equipment.

By comparing the 60 m requirements for propagation delay and delay skew in Table 4 with the measured values in the extreme case of Figure 2, there seems to be no problem associated with those parameters. Therefore, any assessment of length-dependent parameters can focus is on the attenuation/insertion loss and the d.c. loop resistance - for which the latter is independent of Class or Category of cabling. This makes identification of rogue components comparatively straightforward.

More striking, is the fact that the formula for d.c. loop resistance in Table 3 assumes operating temperature of 60 ºC. At 20 ºC the formula is L/100 x 19 + n x 0,4 and this formula that is used to calculate the length-dependent limits in Table 4

Table 4 - Length-dependent requirements

		Link length (m)									**Limit**
Parameter	**Frequency**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	
Attenuation/insertion loss (dB)											
§ Class D	100 MHz	2.9	5.1	7.2	9.3	11.5	13.6	15.7	17.9	20.0	20.4
§ Class E	250 MHz	3.9	7.2	10.5	13.8	17.1	20.4	23.7	27.0	30.3	30.7
§ Class E_A	500 MHz	5.4	9.9	14.5	19.0	23.5	28.0	32.6	37.1	41.6	42.1
§ Class F	600 MHz	6.0	11.0	16.0	21.0	26.0	31.0	36.0	41.1	46.1	46.6
§ Class F_A	1000 MHz	7.5	13.7	19.8	26.0	32.2	38.4	44.6	50.8	57.0	57.6
§ Cat 5e	100 MHz	3.0	5.2	7.4	9.6	11.8	14.0	16.2	18.4	20.6	21.0
§ Cat 6	250 MHz	4.5	7.8	11.1	14.4	17.7	20.9	24.2	27.5	30.8	31.1
§ Cat 6A	500 MHz	7.1	11.6	16.1	20.7	25.2	29.7	34.3	38.8	43.3	43.8
Propagation delay (µs)											
§ Class D/Cat 5e	100 MHz	54	109	163	217	271	326	380	434	488	491
§ Class E/Cat 6	250 MHz	54	108	162	217	271	325	379	433	487	489
§ Class E_A/Cat 6A	500 MHz	54	108	162	216	270	324	378	432	487	489
§ Class F	600 MHz	54	108	162	216	270	324	378	432	486	489
§ Class F_A	1000 MHz	54	108	162	216	270	324	378	432	486	488
Delay skew (ns)											
§ Class D, E and E_A § Cat 5e, 6 and 6A	all	7	12	16	21	25	30	34	39	43	44
§ Class F and F_A	all	5	8	10	13	15	18	20	23	25	26
d.c. loop resistance (Ω) All Classes and Categories	d.c..	3.1	5.0	6.9	8.8	10.7	12.6	14.5	16.4	18.3	21.0

3 ASSESSMENT OF TEST RESULTS

The installation of materials that are not in accordance with the recommendations of University of Oxford IT Services is likely to be undertaken on a project-by-project basis and therefore assessment should only be required on a sample of test results. Any problems will be highlighted by comparing:

- the d.c. loop resistance results obtained for lengths approximating to those of Table 4 with the relevant length-dependent requirements of Table 4 - “correct” cabling will typically produce results that are demonstrably lower than these requirements;
- the attenuation/insertion loss results obtained at the highest frequency of the Class or Category (shown in Table 4) with the relevant length-dependent requirements of Table 4 - “correct” cabling will typically produce results that are demonstrably lower than these requirements.

  NOTE in order to do this comparison; it is imperative that the installer provides the full test result which includes the full characteristic as such as that shown in Figure 3. Failure to provide this information typically prevents a comparison at the maximum frequency of the Class.

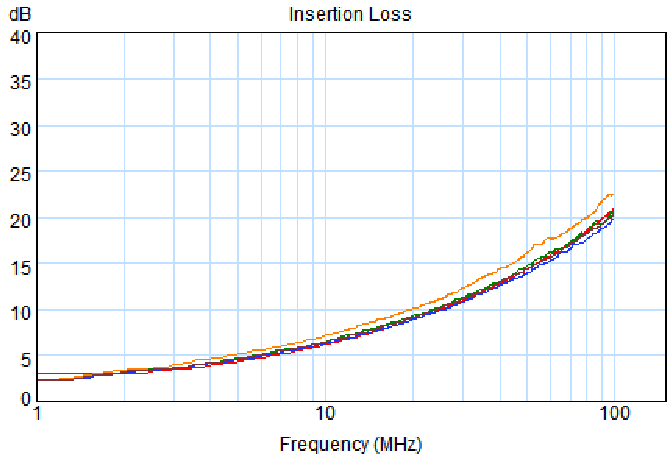


Figure 3 – Attenuation/insertion loss characterstics

4 AVOIDING MISLEADING COMPARISONS

The link length assessed by the test equipment specified in Table 2 is based upon the measured propagation delay multiplied by the nominal velocity of propagation (NVP) of the cable - which is input to the test equipment by the installer. If the NVP is incorrect then the test equipment will provide a similarly incorrect length.

As an example, if the installer inputs and NVP of 63 % but the actual value is 70 % then all lengths will be shown as 10% too short. This obviously can confuse any length-dependent comparisons. If doubts exist then there are two basic methods of resolution:

- checking the supplier specification for the correct NVP value;
- obtaining a known length of cable (perhaps via the cable sheath length markings) and re-validating the NVP.

5 FURTHER INSPECTION

5.1 Copper coated aluminium or steel

There are a number of methods of identifying these types of cables:

- **distribution cables**:
  - once installed, these cables are difficult to identify (apart from their tendency to cause operational problems associated with poor physical stability) but if boxes or reels of these cables are available it will be immediately noticeable that they are lighter than standards-compliant Category-based products;
  - if the cables are cut the non-copper nature of the "core" of the conductor will be noticed in a similar way to that of the cords in Figure 4.
- **cords**:
  - terminated cords can be examined at the terminated plugs as shown in Figure 4;
  - if the cables are cut the non-copper nature of the "core" of the conductor will be noticed in a similar way to that of the cords in Figure 4.

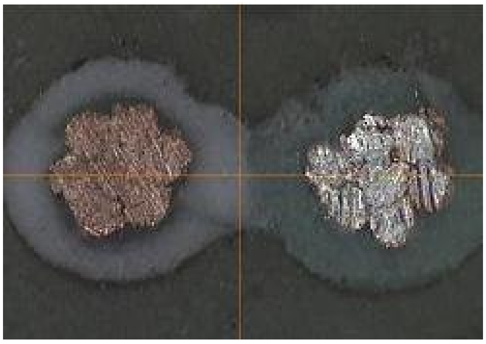
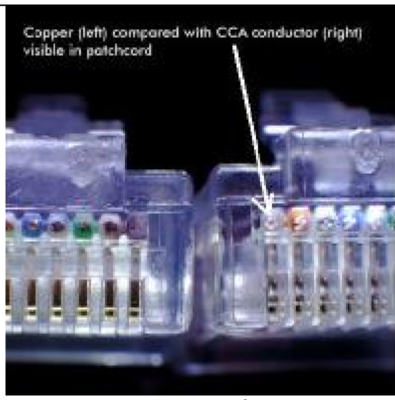
 Image courtesy of Nexans	 Image courtesy of Nexans
Copper vs. copper clad stranded cables	Copper vs. copper clad plug terminations

Figure 4 - Comparisons of clad products with “solid copper” Category-based cables

5.2 Zone cables

These cables are produced typically from 26AWG conductors and are noticeably thinner than the 22 AWG or 24 AWG conductors associated with distribution cables of a given Category.

- 26 AWG (0,41mm diameter);
- 24 AWG (0,51 mm diameter);
- 22 AWG (0,64 mm diameter).

6 OTHER DOCUMENTS IN THIS SERIES

IISS-00-001: Infrastructure Installation Specification Strategy: Overview
IISS-00-002: Infrastructure Installation Specification Strategy: Distributed building services
IISS-01-002: Installation and acceptance testing of singlemode optical fibre cabling

ISP-00-001: Infrastructure Specification Project: Overview
ISP-00-002: Access to University of Oxford IT Services facilities (later)
ISP-01-001: University of Oxford IT Services Entrance Facilities - Product and design specification
ISP-01-002: University of Oxford IT Services Entrance Facilities - Accommodation requirements
ISP-02-001: University of Oxford IT Services Intermediate cabling (INTI-ENTI) - Product and design specification
ISP-02-002: University of Oxford IT Services Intermediate cabling (INTI-ENTI) - Accommodation requirements
ISP-03-001: Distribution cabling - Recommendations: Overview
ISP-03-002: Direct-connect cabling - Recommendations: Telecommunications infrastructure
ISP-03-003: Distribution cabling - Recommendations: IT infrastructure
ISP-03-004: Distribution cabling - Recommendations: Distributed building services infrastructure

BIBLIOGRAPHY

The following documents are considered useful reference sources for the users of this document.

ANSI/TIA-568-2.D	Balanced Twisted-Pair Telecommunications Cabling and Components Standards
ANSI/TIA-1152	Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling.
BS EN 50173 series	Information technology - Generic cabling systems
BS EN 50173-1:2018	Information technology - Generic cabling systems - General requirements
ISO/IEC 11801 series	Information technology - Generic cabling for customer premises
ISO/IEC 11801-1:2017	Information technology - Generic cabling for customer premises - General requirements
BS EN 61935-1:2015	Specification for the testing of balanced and coaxial information technology cabling. Installed balanced cabling as specified in the standards series EN 50173