Data transmission technology:

STANDARDS – INSTALLATION – MEASUREMENT TECHNOLOGY

- Testing and measuring
- Troubleshooting
- Documentation of projects

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On the way to new frontiers

In Local Area Networks (LANs), high-quality copper cabling links form the basis for fast and secure data communication. In the mid-90s, network users were satisfied with data rates of 10 & 100Mb/s, which is no longer considered sufficient today. Today, we operate LANs with data rates of 1 & 10Gb/s and – in data centers – with 25 & 40Gb/s and soon also with 100Gb/s – all using copper cabling.

The latest technologies in multimedia, such as the next generation Wi-Fi (IEEE 802.11ac/ax) and Ultra-HDTV (such as 4K/8K and 16K) are driving faster transmission speeds – and thus the bandwidths – in copper data networks to new heights. To ensure system warrantees and proper functioning of these high-speed copper data networks, this requires measuring and testing these copper cabling systems.

The field measurement technology and the measurement technician and installer must be prepared for these changes. The cabling industry is talking about Cat 8, Cat 8.1, Cat 8.2 and Class I & II, all of which will be covered in this manual. We are continuing the tradition of summarizing all questions concerning measurement and testing technology for these high-speed copper data networks in a practical and small manual.

The first edition of this cabling handbook was published in 2007, and this new 2022 edition of the “Handbook of Cabling and Measurement Technology” should find its place in the toolbox or measurement equipment bag of every data cabling and measurement technician and installer: Always on hand, quick to look up, with comprehensive up-to-date information.

We wish you smooth installations and acceptance measurements of copper data cabling.

With kind regards

Dipl.-Ing. (FH) Thomas Hüsch
Technical Support & Training, Softing IT Networks GmbH

CONTENT

DATA TRANSMISSION TECHNOLOGY:

STANDARDS – INSTALLATION – MEASUREMENT TECHNOLOGY

PRINCIPLES OF NETWORK TECHNOLOGY

This manual deals with data transmission technology from network development, standards, acceptance measurements and troubleshooting to documentation. Did you know that the well-known and popular Ethernet is more than 40 years old and that the standardization of Ethernet by IEEE 802 with the first 802.3 standard also began more than 30 years ago?

The use of computers, smart TVs, telephone systems with VoIP technology as well as building communication (door intercoms, alarm systems) has become commonplace. Not so long ago, separate communication networks were used for this purpose: twisted wires for the telephone, coaxial lines for television and chunky Twinax data cables (IBM) for the first office computer systems. Today, however, "Ethernet" has become the standard for communications technology and is used equally by various trades. Today, the term "Ethernet" refers to the physical interface (cables, connectors) as well as the transmission protocol as the basis for the well-known "TCP/IP" world – the logical functions of network components.

In this manual, however, the focus is on one of the physical transmission media of the Ethernet, which has established itself as GCS ("Generic Cabling System"). Even as an electrician, you must deal with its planning, installation, acceptance measurement and its operation.

First, we want to look at the basics of our current network infrastructure.

We always talk about the so-called „Universal Structured Building Cabling" – what is meant by this and what standards exist for it?

CHAPTER 1:

REVIEW, HISTORY

Figure 1: Ethernet inventor Bob Metcalfe is now Professor of Innovation at the University of Texas at Austin, Texas, USA; *Source: UTECE*

THE DEVELOPMENT OF THE ETHERNET

Here are some historical data from the mouth of Robert "Bob" Melancton Metcalfe ***(see Figure 1)***, the inventor of the Ethernet and now Professor of Innovation at the University of Texas at Austin, who comments on the joyous event in 2013: "On May 22, 2013 we celebrated the 40th anniversary of the invention of the Ethernet at Xerox PARC. Now, on June 23, 2013, we are celebrating the 30th anniversary of Ethernet standardization through IEEE 802." Of course, Ethernet has been standardized many times since 1983, when IEEE 802.3 adopted the rapid innovations from 2.94 Mbps to 400Gb/s, from thick to thin coaxial cables, to twisted pairs and finally fiber-optic cables, as well as Wi-Fi, from CSMA/CD bus networks to switches and access points. At the same time, a high degree of backward compatibility was ensured. "In 1983 there were people who bought Ethernet and whom I did not know personally. In 1985 there were even people I did not know who invented Ethernet. And they continue to do so today with great success, using the open standardization process of the IEEE. Congratulations and many thanks," Metcalfe continues *(source: IEEE SA)*.

INCREASING DATA RATES

And speeds have also increased and continue to increase today ***(see Figure 2)***. The twisted-pair cabling systems used today have developed rapidly over the last ten years. While in 1995 networks with transmission rates of 10 & 100Mb/s were still being set up and operated, the speed in our networks has increased by two decades (factor 100) since then. Since the year 2000, copper-based networks with transmission rates of 1Gb/s have been set up and operated, initially in data centers and now also at the workplace. At present, networks with transmission rates of 10Gb/s according to the Cat 6A / Class E_A have been installed and operated for several years.

Initially, these are mainly found in data centers for connecting high-performance servers to corresponding switches and storage systems. But just as this development has been seen repeatedly in the past, today's servers are still our desktops of tomorrow – both in terms of the performance of the computers and their connection to the network. Another milestone was set on 17 June 2010. The "IEEE 802.3ba – 40Gb/s and 100Gb/s Ethernet Task Force" adopted the standard for the transmission of 40Gb/s over copper cabling and 40 / 100Gb/s over fiber-optic cabling.

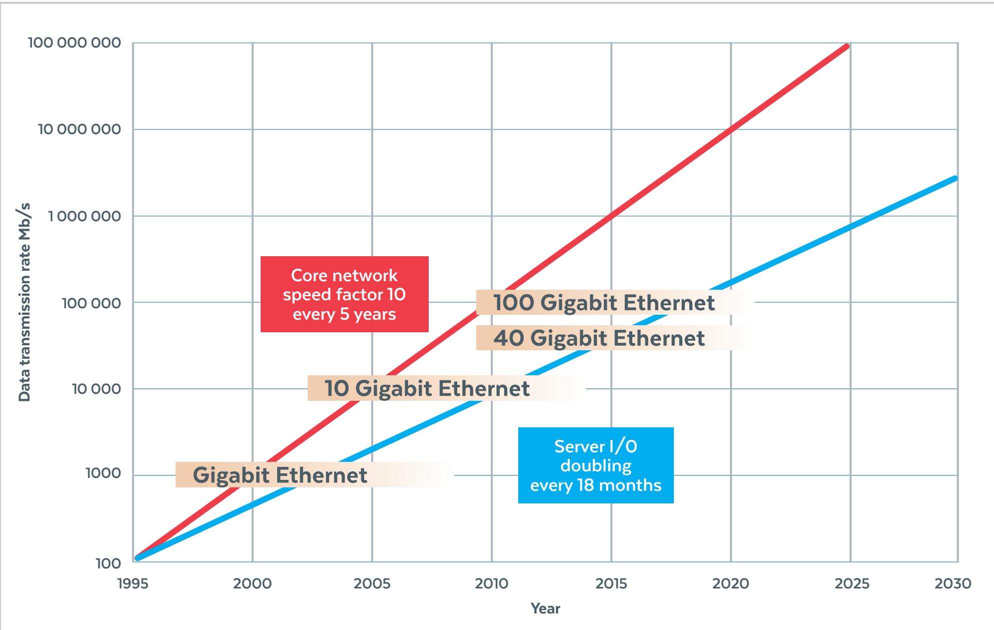


Figure 2: Increase in bandwidth requirements in networks and data centers

CHAPTER 2:

THE STRUCTURED CABLING

THE STANDARDS FOR CABLING

On June 30, 2016, the responsible IEEE committee announced the adoption of the new Ethernet standard 802.3bq for 25GBase-T and 40GBase-T over copper applications.
And that is not all, the next goals of IEEE 802.3 have again been addressed. On Dec 8, 2021, the IEEE P802.3df Project Authorisation Request (PAR) was approved and shortly after that the "IEEE P802.3df Ethernet Task Force" started the work on new Ethernet standards with speeds of 200Gb/s, 400Gb/s, 800Gb/s, and 1.6Tb/s for future use in datacenter networks.

While Ethernet transmission standards describe data transmission, cabling standards describe the infrastructure. These cabling standards describe the layout as well as the transmission properties derived from the transmission requirements written in IEEE 802.3.

This structured cabling, also known as Universal Structured Building Cabling, represents a uniform layout plan for cabling for different services such as voice, data, video, control systems, etc. for structured cabling, the International Committee for Electrotechnical Standardization (ISO/IEC) has published the International Standard ISO/IEC 11801 for application-neutral cabling systems, in USA the ANSI/TIA-568 Cabling Standards have been published by the Telecommunications Industry Association (TIA), that is accredited by the American National Standards Institute (ANSI). In Europe the CENELEC has published the EN 50173 Cabling Standard following the ISO/IEC 11801 standard.

THE STRUCTURED CABLING

Structured cabling is part of the technical infrastructure of a property and is divided into primary, secondary and tertiary cabling areas.

Primary cabling area – on the campus

This cabling ***(see Figure 3)*** connects the buildings of a site with each other and is also called campus cabling or site cabling and includes both the connections of the site distributor with the building distributors as well as optional tie connections between the building distributors of the different buildings for redundancy reasons.

The media used for data technology applications today typically consist of fiber-optic cables (single-mode and/or multi-mode) and for analog and/or digital telephony still sometimes copper cables. The digital voice transmission Voice over IP (VoIP) is today almost transmitted via fiber-optic cables.

Secondary cabling area – in the building

It is the vertical building cabling or backbone cabling and includes both the connection of the building distributor with the floor distributors and optional tie connections between the floor distributors – for redundancy reasons. If the distances between the building and the floor distributors or between the floor distributors in the riser area are less than 100m (in the Channel) and data transmission rates of 10Gb/s are sufficient, copper cables can now also be used in the riser area. However, it must be ensured that there are no ground potential differences between the floors.

Tertiary cabling area – on the floor

The tertiary area is the horizontal floor cabling and includes the cabling from the floor distributors to the working areas. The media used are typically copper cables and/or fiber-optic cables (only multi-mode approved), whereby the first connection in the working area must be a copper connection in accordance with standard at least Cat 5e / Class D (ANSI/TIA 568.2-D / ISO/IEC 11801-2 / EN 50173-2). A further connection can optionally be designed as a copper (Cat 5e/Class D) or duplex fiber-optic connection (multi-mode). The length in the tertiary area should not exceed 100m. The total length of the cabling of the three areas (primary, secondary, tertiary) should not exceed 2000m in office buildings.

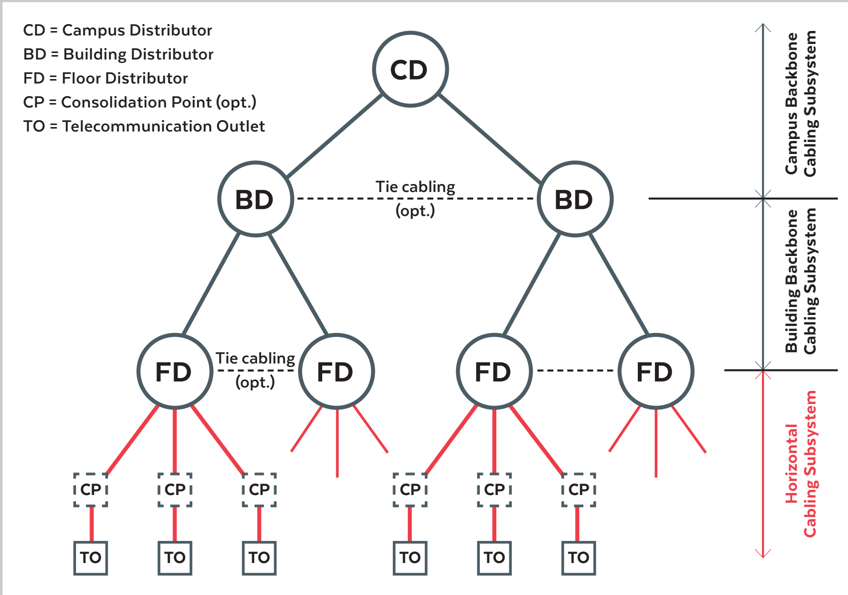


Figure 3: The areas of structured cabling; ISO/IEC 11801-1 / EN 50173-1 / ANSI/TIA 568-0.E; *Source: Softing IT Networks*

CATEGORIES AND CLASSES

The structured cabling systems today consist mainly and especially in the horizontal area of copper cabling, so we will first deal with the copper cabling lines. Today, you will find mainly cabling of the Classes D, E, E_A, F, F_A and Class I & II according to the European and international standards, as well as Cat 5e, 6, 6A and 8 according to the American standards.

What does Class or Cat actually mean in this context?
These Classes and Categories describe the transmission performance and the composition of the cabling routes.

The transmission lines consist of cables, connection components and patch cords of a certain category. Cables and connectors are interconnected to form a cabling link (the permanent link or permanent components inside the building). When you add patch cables, for example when testing, or for interconnections in a distribution panel, this is called a transmission link.

The entire transmission link is given a Category rating in American standards, or a link Class rating for International and European standards.

Table 1 shows how the component Categories and Link Categories/Classes are related. In principle, the principle of the weakest member in the chain, which determines overall performance, also applies here. This means that if you connect a Category 6A cable with Category 5e components, you only get a Cat 5e / Class D link.

The Classes and Cat are characterized by the upper frequency limit, i. e. a Class E_A / Cat 6A has an upper frequency limit of 500MHz and a Class D / Cat 5e of 100MHz. The previous highest Class F_A had an upper frequency limit of 1000MHz and no equivalent in ANSI/TIA ***(Table 2)***.

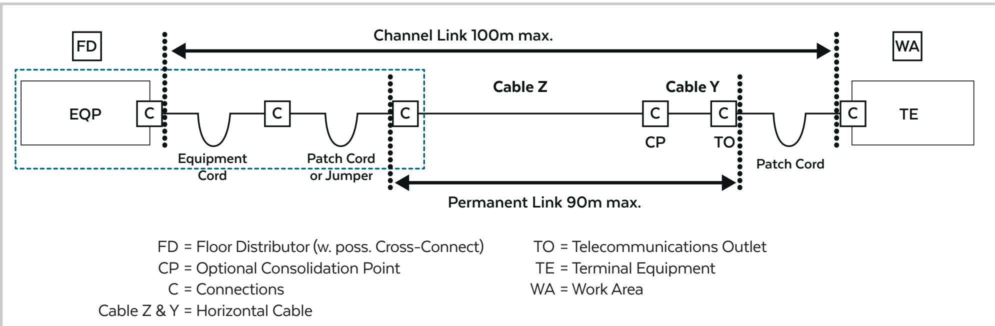
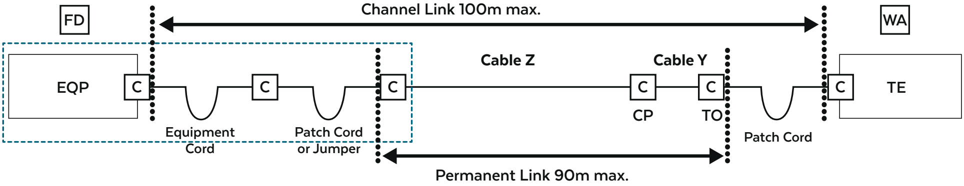


Figure 4a: Transmission path (channel) and cabling path (permanent link) according to ISO/IEC 11801-2 & EN 50173-2; *Source: Softing IT Networks*



Cables and cords

Work area cord . . . . A
Optional consolidation point cabling . . . . B
Horizontal cabling C
Patch cord or jumper cable . . . . D
Telecommunications room equipment cord . . . . E

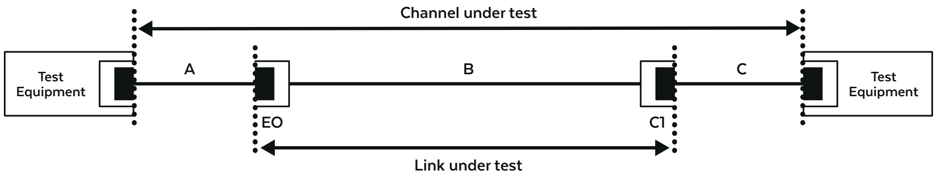
Connecting hardware

Telecommunications outlet/connector . . . . TO
Optional consolidation point connector . . . . CP
Horizontal cross-connect or interconnect C1, C2

Maximum length

B + C 90m (295ft)
A + D + E 10m (32.8ft)

Figure 4b: Transmission path (Channel) and cabling path (Permanent Link) according to ANSI/TIA 568.2-D, Cat 3 to 6A);
Source: Softing IT Networks



Cables and cords

Equipment cord . . . . A, C
Horizontal cabling . . . . B

Connecting hardware

Equipment outlet . . . . EO
Interconnect C1

Maximum length

A + C . . . . see table
B (TIA) 24m (79ft)

Equipment cord de-rating factor (%)	Length of cordage allowed (m)
0	7.2
20	6
50	4.8

Figure 4c: Category 8 Channel & Permanent Link configuration acc. to ANSI/TIA-568.2-D); *Source: Softing IT Networks*

Installation Cable	Connecting Hardware							
Class/ Category	Cat 5 / Cat 5e	Cat 6 / Cat 6	Cat 6_A / Cat 6A	Cat 7 / -	Cat 7_A / -	Cat 8.1 / Cat 8	Cat 8.2 / -
Kat 5 / Cat 5e	Class D / Cat 5e	Class D / Cat 5e	Class D / Cat 5e	Class D / -	Class D / -	Class D / Cat 5e	Class D / -
Kat 6 / Cat 6	Class D / Cat 5e	Class E / Cat 6	Class E / Cat 6	Class E / -	Class E / -	Class E / Cat 6	Class E / -
Kat 6_A / Cat 6A	Class D / Cat 5e	Class E / Cat 6	Class E_A / Cat 6A	Class E_A / -	Class E_A / -	Class E_A / Cat 6A	Class E_A / -
Kat 7 / -	Class D / -	Class E / -	Class E_A / -	Class F / -	Class F / -	Class E_A / -	Class F / -
Kat 7_A / -	Class D / -	Class E / -	Class E_A / -	Class F / -	Class F_A / -	Class E_A / -	Class F_A / -
Kat 8.1/ Cat 8	Class D / Cat 5e	Class E / Cat 6	Class E_A / Cat 6A	Class F / -	Class F_A / -	Class) I / Cat 8	Class) I / Cat 8
Cat 8.2/ -	Class D / -	Class E / -	Class E_A / -	Class F / -	Class F_A / -	Class) I / -	Class) II / -

Table 1: Installation Cable and Connectors – Matrix for Classes and Categories

CATEGORIES AND CLASSES		
Frequency	**ANSI/TIA**	**ISO/IEC / CENELEC**
100MHz	Cat 5e	Class D
250MHz	Cat 6	Class E
500MHz	Cat 6A	Class E_A
600MHz	-	Class F
1000MHz	-	Class F_A
1250MHz	Cat 8	Class I & II
2000MHz	Cat 8	Class I & II

Table 2: Relationship between frequencies, Categories and Classes

For a long time, it was believed that Class F_A with 1000MHz would be sufficient to be able to transmit future transmission rates of 40Gb/s. However, through the input of various working groups, it was concluded that 1000MHz was not sufficient. In September 2012, for example, ANSI/TIA working group TR42.7 took the first steps towards a higher bandwidth and started work on Cat 8 with an upper frequency limit of 2000MHz.

This approach was based on well-known connector technology, the RJ45 connector, but in an improved Cat 8 version and because of the high attenuation of copper cables with a shorter channel length of 30m. The ISO working groups had also made proposals for the next generation of cabling systems, with one proposal being based on previous Cat 7_A components and covering a bandwidth of up to 1200 and 1600MHz.

Another approach, Class I, is based – like ANSI/TIA – on the well-known RJ45 connector in Category 8.1 design and is defined, as in the ANSI/TIA proposal, with a bandwidth of up to 2000MHz. Another approach, Class II, is based on Category 8.2 components and a bandwidth up to 2000MHz ***(Table 3)***. All approaches of the working groups were based on a reduced transmission channel length of 30m.

Apart from the growth in wireless and fiber-optic infrastructures, copper cabling will continue to be the dominant medium in the foreseeable future. When planning network infrastructures for data centers, taking into account life cycles of at least ten years, new standards should be considered today and – both in terms of installation and acceptance measurements – be prepared for the near future of 25 & 40Gb/s.

NEW CLASSES AND CATEGORIES IN COMPARISON			
Ext. Class F_A 1250 MHz	Class I 2000 MHz	Class II 2000 MHz	Cat 8 2000 MHz
Cat 8.2-components	Cat 8.1-components	Cat 8.2-components	Cat 8-components

Table 3: From new, extended Class F_A to Cat 8

COMPLEX RELATIONSHIPS IN STANDARDIZATION

Now we are dealing with the structure of the standards on the transmission components and quality Classes of structured copper cabling. The differences between the American standards and the standards valid worldwide / in Europe must be taken into account. So far the standards defined the highest Class F_A, but now Cat 8 (ANSI/TIA) and Class I & II (ISO/IEC & EN) are added. How are the connections to be seen and where do we stand with the standards today? Up to now, the standards described the properties up to and including Cat 6A / Class F_A, but today we are moving on: Cat 8 and Class I & II.

Figure 5 shows the relationship between the individual standardization committees. Here, the ISO/IEC 11801 standard is considered the "mother" of all cabling standards, with the "children" such as ANSI/TIA and EN sometimes making some headway and the "mother" organization then having some catching up to do. In principle, the ISO/IEC 11801 standard is an internationally valid standard, with which more than 90 nations (35 member countries and 57 observing nations) have dealt with the topic of structured cabling. The standards ANSI/TIA-568-0.E (USA) and CENELEC EN 50173-x (Europe) are only locally valid. We will now go into the differences in more detail.

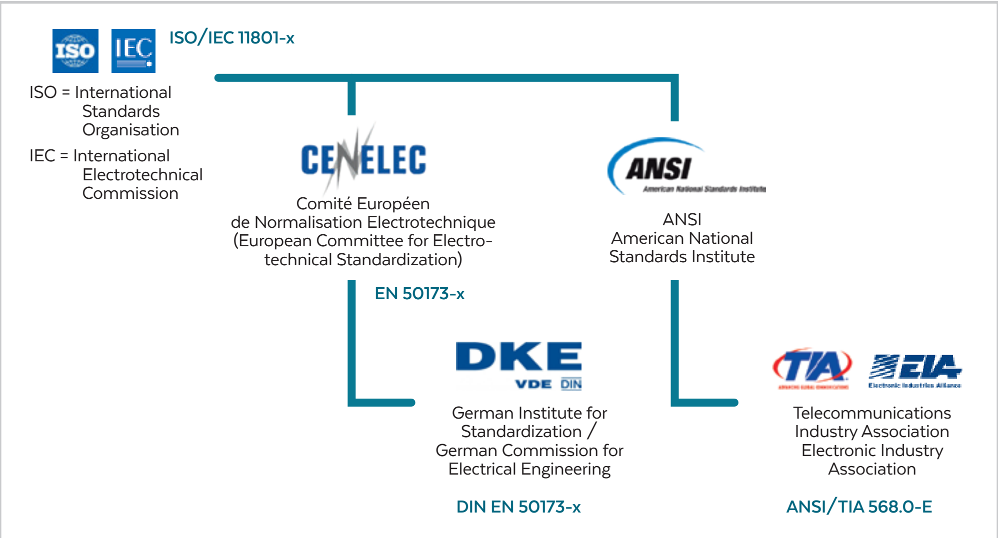


Figure 5: Overview of the standardization bodies

IT STARTED IN THE USA

Let us start with ANSI/TIA 568, the American standard that defines both the connectors and cables and the transmission paths resulting from the assembly of these components in “Categories” (Cat x) ***(see Table 4)***. These standards describe the quality levels Cat 5e to Cat 8, which cover the frequency ranges from 1MHz to 2000MHz and specify the limits for data transmission of 10/100Mb/s, 1/2.5/5/10Gb/s and 25 & 40Gb/s. The latest addition is the Cat 8 quality level, with Cat 8 components and Cat 8 cables, which are sufficient for transmitting 25 & 40Gb/s at a frequency of up to 2000MHz.

Table 4 is an extension of ***Table 1*** to include the applications. Up to now, the definitions and standard specifications ended at a physical limit frequency of 1000MHz and a transmission bit rate of 10Gb/s – enormous values, if you look back at the limit values with which we started in the 1990s.

STANDARDS, VALID WORLDWIDE/IN EUROPE

The worldwide/European standards ISO/IEC 11801-x and EN 50173-x define the quality characteristics of connectors, cables and the cabling and transmission paths. A distinction is made here between “categories” from Cat 5e to Cat 8.2 (for the components) and “Classes” (for the transmission paths).

FREQUENCY, CATEGORY/CLASS, APPLICATION			
Frequency	**ANSI/TIA**	**ISO/IEC / EN**	**Application**
100MHz	Cat 5e	Class D	10, 100Mb/s, 1 & 2,5Gb/s
250MHz	Cat 6	Class E	5Gb/s
500MHz	Cat 6A	Class E_A	10Gb/s
600MHz	-	Class F	-
1000MHz	-	Class F_A	-
1250MHz	Cat 8	Class I & II	25Gb/s
2000MHz	Cat 8	Class I & II	25 & 40Gb/s

Table 4: The Category (USA) or Class (International & Europe)

These Classes D (2002) to Class II are used in the frequency range from 1 to a maximum of 2000MHz and for the transmission of digital data at 10/100Mb/s, 1/2.5/5/10Gb/s and 25 & 40Gb/s.

The most recent additions are

- **Class I** with cables of Category 8.1 (mostly F/UTP, overall foil shield, unshielded twisted pairs) and components of Category 8.1 (RJ45) and the
- **Class II** with Category 8.2 cables (always S/FTP, overall braided shield, in pairs foil-shielded twisted pairs) and Cat. 8.2 components sufficient for 25 & 40Gb/s transmission – see also **Table 4**.

So there will be two different standards:

1.1 which in the case of the Cat 8 (USA) with Cat 8 connectors and Cat 8 cables will only be backward compatible with the Cat 6A ***(see Table 5)*** and

1.2 in the case of Class I with the improved Cat 8.1 connectors and Cat 8.1 cables only backwards compatible with Class E_A ***(see Table 6)***, and

2 in the case of Class II with Cat 8.2 connectors and Cat 8.2 cables are backwards compatible with Class F and F_A ***(see Table 7)***.

Installation cables and connectors – Overview

Cat 8		Connectors					
		Cat 5e	Cat 6	Cat 6A	-	-	Cat 8
Installation cable	Cat 5e	Cat 5e	Cat 5e	Cat 5e	x	x	Cat 5e
	Cat 6	Cat 5e	Cat 6	Cat 6	x	x	Cat 6
	Cat 6A	Cat 5e	Cat 6	Cat 6A	x	x	Cat 6A
	-	x	x	x	x	x	x
	-	x	x	x	x	x	x
	Cat 8	Cat 5e	Cat 6	Cat 6A	x	x	Cat 8

Table 5: Backwards compatibility of connectors and installation cables, ANSI/TIA 568.0-E, US standard, gaps for Cat $7/7_A$ components and cables not available in the ANSI/TIA 568.0-E standard

Installation cables and connectors – Overview for Class I (RJ45 technology)

Class I		Connectors					
		Cat 5	Cat 6	Cat 6_A	Cat 7	Cat 7_A	Cat 8.1
Installation cable	Cat 5	Class D	Class D	Class D	Class D	Class D	Class D
	Cat 6	Class D	Class E	Class E	Class E	Class E	Class E
	Cat 6_A	Class D	Class E	Class E_A	Class E_A	Class E_A	Class E_A
	Cat 7	Class D	Class E	Class E_A	x	x	x
	Cat 7_A	Class D	Class E	Class E_A	x	x	x
	Cat 8.1	Class D	Class E	Class E_A	x	x	Class I

Table 6: ISO/IEC backward compatibility of Cat 8.1 connectors in combination with Cat 8.1 installation cables (F/UTP, overall foil shield, unshielded twisted pairs), gap in Class F and F_A

Installation cables and connectors – overview for Class II (non-RJ45 technology)

Class II		Connectors					
		Cat 5	Cat 6	Cat 6_A	Cat 7	Cat 7_A	Cat 8.2
Installation cable	Cat 5	Class D	Class D	Class D	Class D	Class D	Class D
	Cat 6	Class D	Class E	Class E	Class E	Class E	Class E
	Cat 6_A	Class D	Class E	Class E_A	Class E_A	Class E_A	Class E_A
	Cat 7	Class D	Class E	Class E_A	Class F	Class F	Class F
	Cat 7_A	Class D	Class E	Class E_A	Class F	Class F_A	Class F_A
	Cat 8.2	Class D	Class E	Class E_A	Class F	Class F_A	Class II

Table 7: ISO/IEC backward compatibility of Cat 8.2 connectors in combination with Cat 8.2 installation cables (S/FTP, overall braided shield, pairs of foil-shielded wire pairs)

WHAT DO THE TABLES SAY NOW IN COMPARISON?

The ISO/IEC standard (International) allows the seamless implementation of all link Classes (from Class D to Class II, ***Table 7***) when using S/FTP cables. In contrast, when using the F/UTP cable ***(Table 6)*** and according to the ANSI/TIA 568.0-EANSI/TIA 568.0-EANSI/TIA 568.0-EANSI/TIA 568.0-E standard for Cat 8 ***(Table 5)***, there are incompatibilities (not feasible, not standardized) between some connector and cable types, so that Class F and F_A are not met. The crosses in ***tables 5 and 6*** indicate the connector-cable combinations that are not practical. In the worst case, only Cat 6A ***(Table 5)*** and Class E_A ***(Table 6)*** are obtained. When specifying and selecting the components, it is therefore important to note which standard should apply.

IMPROVED CONNECTORS

What do Cat 8, Cat 8.1 and Cat 8.2 connectors mean?

The main features of the Cat 8/Cat 8.1 connectors are that they are based on our previous RJ45 connectors of the Cat 6A and Cat 6_A, but their performance has been trimmed to 2000MHz.

Considering that the original RJ45 connector was designed for transmission bandwidths of 6MHz and is now used in Cat 6A and Cat 6_A versions up to 500MHz and is now used up to 2000MHz, it is surprising that this works. But some connector manufacturers are already supplying them, and who would have thought the RJ45 connector could reach 500MHz about 20 years ago? And it worked! So, in the future we will see improved versions of the RJ45 connector even with 2000MHz installations.

This looks much better with the Cat 8.2 connector components. These have been further developed from the existing Cat 7_A connector systems, i. e. TERA, GG45, ARJ45 and MMC Pro connectors have been tuned to 2000MHz at best by minor improvements. You can imagine this a bit earlier with these connectors, since they, with the exception of the GG45 connector, have nothing to do with the RJ45 connector face, so they are also not backward compatible with the RJ45 connector.

Note: The GG45 specification describes a jack that is backwards compatible with the RJ45 connector, which then has Cat 8.2 characteristics by switching contact pairs 3-6 and 4-5 to the back of the connector and using the ARJ45 connector.

HIGHER REQUIREMENTS FOR THE CABLES

For the installation cables, this was already a greater challenge, because the characteristics of twisted-pair copper cables are characterized by the fact that the attenuation also continues to rise with increasing frequency ***(see Figure 6)***. At 2000MHz, the attenuation of a 100m transmission channel of Class F_A would already be around 99dB at 2000MHz. Since such a value is outside the currently usable range for active components, it was necessary to reduce the effective attenuation for transmission via Cat 8, Cat 8.1 and Cat 8.2 installation cables. The only reasonable way to get the attenuation into a usable range was to shorten the cabling length. Therefore, for Cat 8, Class I and Class II transmission, a reference length of the transmission channel of 30m has been agreed upon, thus deviating from the previously standard of 100m.

A further problem is the alien crosstalk (crosstalk from neighbor lines/interference from outside) ***(see Figure 7)***. For this reason, all standardization committees have agreed the transmission of 40Gb/s via shielded cabling systems. Even among the die-hard lovers of UTP (unshielded) cables (i. e. also some of the staff in the American standardization), shielded cables are set at Cat 8, and in the ISO/IEC, agreement has been reached on at least F/UTP cables for Category 8.1 ***(see Figure 8)*** and S/FTP cables for Category 8.2 ***(see Figure 9)***.

Attenuation Channel Class F_A up to 2000MHz

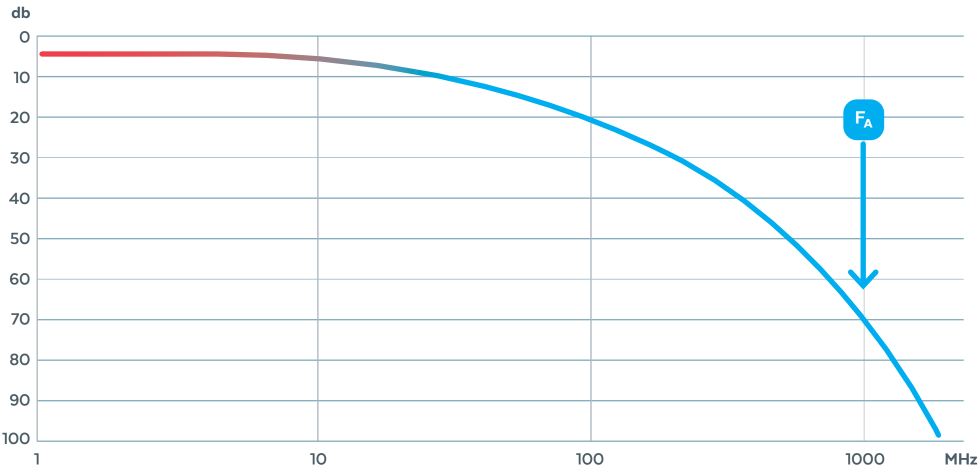


Figure 6: Attenuation curve of Class F_A as a function of frequency; *Source: Softing IT Networks*

Note: Hardly noticeable, but the twist lengths of the individual wire pairs differ and thus improve near-end crosstalk.

Considering the higher attenuation and the more sensitive near-end crosstalk, there was no other option than to use only shielded cables for the new transmission Classes.

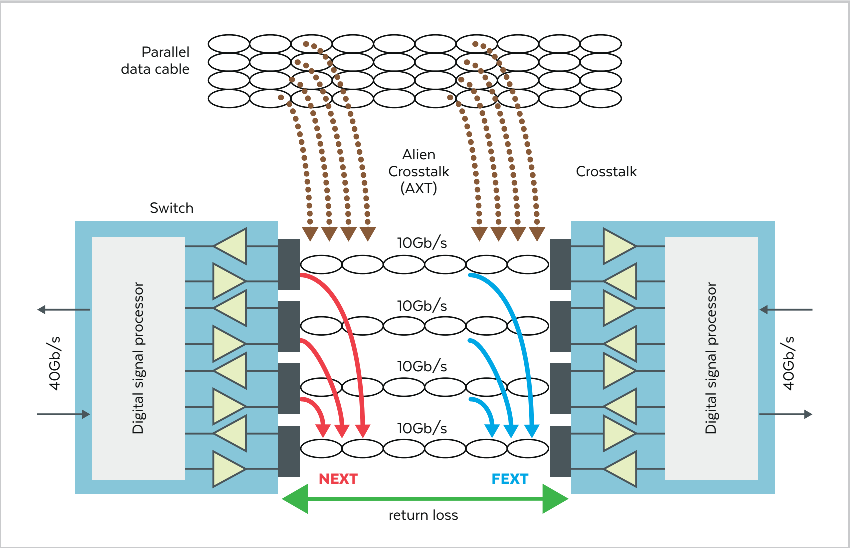


Figure 7: Diagram of parallel lines and their disturbance variables

Figure 8: Data cable, F/UTP category 8.1, shielded; *Source: Leoni Kerpen*

Figure 9: Data cable, S/FTP category 8.2, shielded; *Source: Leoni Kerpen*

CONSIDERATION OF FURTHER TRANSMISSION PARAMETERS

The transmission properties of the transmission links (channel) depend on a number of other transmission parameters.

The most important parameters to be mentioned here are

- The Near End Cross Talk (NEXT), and
- the return loss (RL = Return Loss).

Cat 8, Class I and Class II are, as we have already described, partly further developments of existing transmission standards.

For ANSI/TIA Cat 8, the previous transmission parameters have been further calculated according to Cat 6A up to 2000MHz. For example, the limit for attenuation at Cat 8 with reduced length will be max. 35.6dB.

The situation is similar for Class I and Class II, here too the values of Classes E_A and F_A were further calculated and end up at 2000MHz with a maximum attenuation of 32.7dB (Class I) and 30.8dB (Class II) ***(see Figure 10)***, the minimum attenuation of NEXT values ***(see Figure 11)*** are 9.6dB (Class I) and 27.7dB (Class II) and the minimum return loss values ***(see Figure 12)*** are 6.2dB (Class I and Class II). In the standardization for the transmission of 40Gb/s over Cat 8 copper cabling systems, the American working groups have already adopted the ANSI/TIA 568.0-E standard; the standardization for Class I & II is also ready. The application of the 25 & 40Gb/s standards is aimed at cabling and transmission systems in data centers because of their shorter lengths.

However, data applications in connection with Ultra-HD, the next standard of higher resolution in the video and television environment, must also be considered. Here, considerably larger amounts of data will have to be transmitted in data centers, which requires more bandwidth. But as developments in the past have already shown, today's servers will become tomorrow's desktops, and at some point in time we may need 25 or 40Gb/s in horizontal cabling?

Insertion Loss limits from Class D to Class II for Channel Link

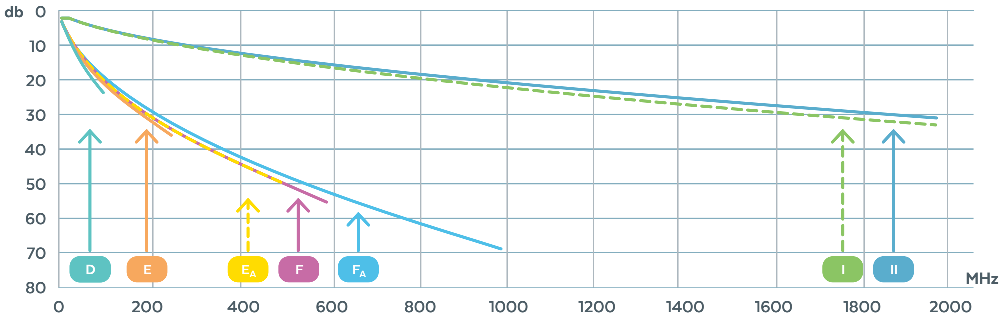


Figure 10a: Insertion Loss limits for the different Classes according to ISO/IEC for Class D to Class II cabling; *Source: Softing IT Networks*

Insertion Loss limits from Category 5e to 8 for Channel Link

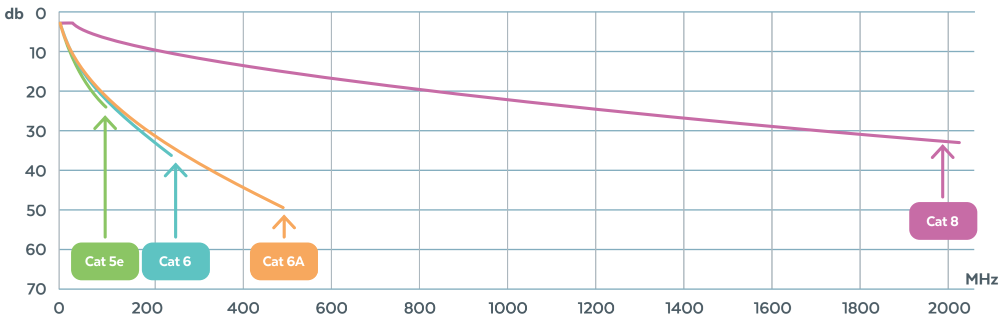


Figure 10b: Insertion Loss limits for the different Categories from Cat 5e to 8 acc. to ANSI/TIA568; *Source: Softing IT Networks*

NEXT limits from Class D to Class II for Channel Link

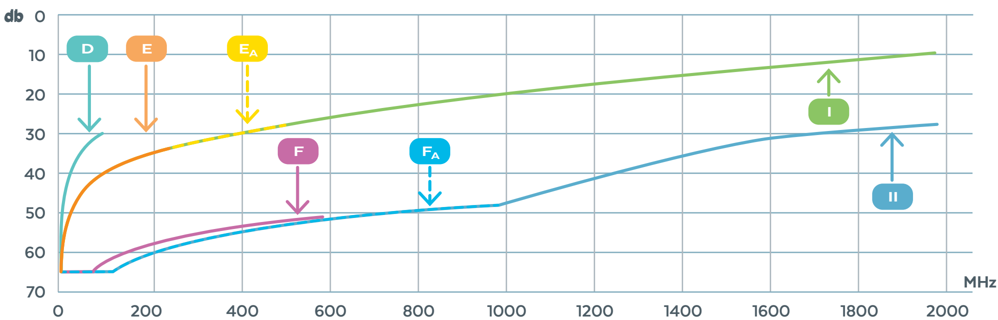


Figure 11a: NEXT limits for the different Classes according to ISO/IEC for Class D to Class II cabling; *Source: Softing IT Networks*

NEXT limits from Category 5e to 8 for Channel Link

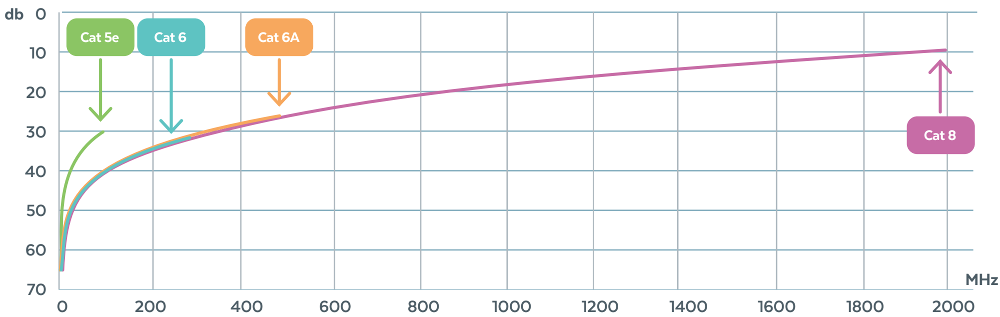


Figure 11b: NEXT limits for the different Categories from Cat 5e to 8 acc. to ANSI/TIA568; *Source: Softing IT Networks*

Return Loss limits from Class D to Class II for Channel Link

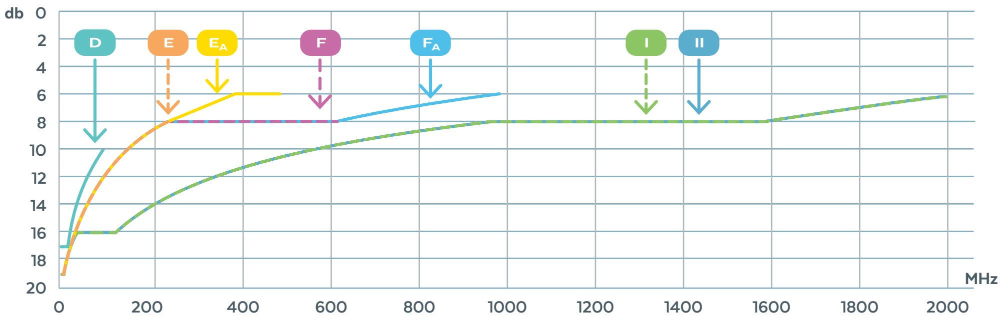


Figure 12a: Return loss limits for the different Categories from Cat 5e to 8 acc. to ANSI/TIA568; *Source: Softing IT Networks*

Return Loss limits from Category 5e to 8 for Channel Link

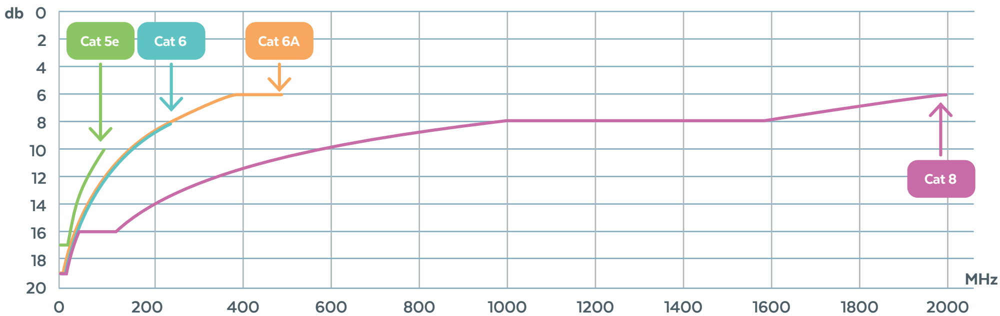


Figure 12b: Return loss limits for the different Categories from Cat 5e to 8 acc. to ANSI/TIA568; *Source: Softing IT Networks*

CHAPTER 3:

MEASUREMENT TECHNOLOGY

MEASUREMENT TECHNOLOGY ON COPPER CABLING – NEW CHALLENGES

Now we will look in detail at the measurement technology for copper cabling. First, we describe the already known measurement parameters and also deal with the measurement technology for the copper transmission systems of the new transmission Classes up to 2000MHz.

The new transmission Classes pose new challenges for measurement technology. For example, the measuring instruments for the new transmission Classes Cat 8 (ANSI/TIA standard), Class I and Class II (ISO/IEC / EN standards) must be able to measure at least up to a frequency of 2000MHz, perhaps a little further from experience.

To be able to carry out correct measurements, you not only need a suitable measuring device, but the correct measurement setup is also important. Unfortunately, there are still confusions that lead to faulty measurements on one hand and finally to wrong measurement results on the other hand.

We are talking about the so-called Channel and Permanent Link measurements and – since the last ISO/IEC Technical Reports, also about E2E and MPTL measurements, what is this all about?

DEFINITIONS OF THE TRANSMISSION LINKS

The standards always define the channel (transmission channel) first, i. e. they describe the entire transmission path. The transmission channel is the entire connection between the active components, such as the application-specific transmission device (EQP; usually a switch) on the one end and the terminal equipment (TE = most a network interface card = NIC) on the other end ***(see Figures 4a & 4b)***.

What is this all about? This concerns the installation cable that the installer has laid (usually these are pulled in), furthermore the connection components in the distribution room, usually distribution panels – or modules that are inserted in distribution panel frames – and in the work area the workplace connection as a junction box – or as a module in a corresponding frame. These permanently installed parts of the cabling are then also called the Permanent Link by the standards ***(see Figures 13a & 13b – explanations see Figure 4)***. In a few special cases the permanent link also includes additional Consolidation Points (CP), mostly floor boxes as intermediate distributors in the respective office room. These components are part of the Permanent Link.

If you then connect the flexible patch cords on both sides, the channel is complete ***(see Figures 13a & 13b)***. The patch cords must be the same as the ones that will be available there later during operation. If you remove these patch cords and replace them with others, the standards require a new measurement of the channel!

Unfortunately, this happens again and again in installations that the installers who carries out the acceptance measurements perform them with the channel adapters on the measuring device and two 2 – 5m long patch cables, without knowing that these channel measurements will cause a falsification of the measurement results up to the point of uselessness of the measurement data, because on the one hand they want to save the money for somewhat more expensive measurement cables for the Permanent Link measurement and on the other hand they then falsify the length of the link by these two patch cable lengths for each Permanent Link.

Furthermore, the durability of patch cables with standard RJ45 plugs is limited. The durability is limited to approx. 750 mating cycles. This means that these "measuring cables" have an extremely limited service life. This quickly leads to completely faulty acceptance measurements. Today's permanent link measuring cables have a service life of up to 5000 mating cycles due to the use of significantly improved RJ45 measuring plugs and careful handling, which again justifies the somewhat higher purchase price of these measuring cables.

Important! According to the standards, the acceptance measurement after an installation must always be carried out as a permanent link measurement, since the permanent link is normally not changed after installation and documents the service provided by the installation company.

In addition, there are now a few more installation variants from the industrial sector (ANSI/TIA-1005-A / ISO/IEC 11801-3 / EN 50173-3) and from the building automation sector (ANSI/TIA-862-B / ISO/IEC 11801-6 / EN 50173-6). More about this later.

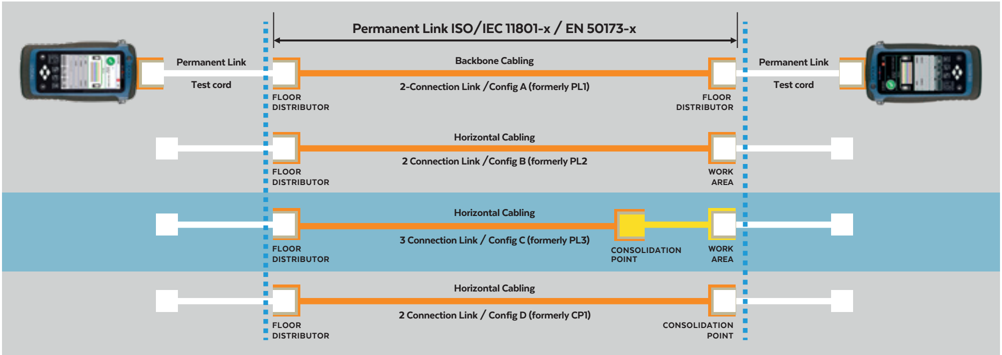


Figure 13a: Permanent link measurements according to ISO/IEC 11801-x / EN 50173-x; *Source: Softing IT Networks*

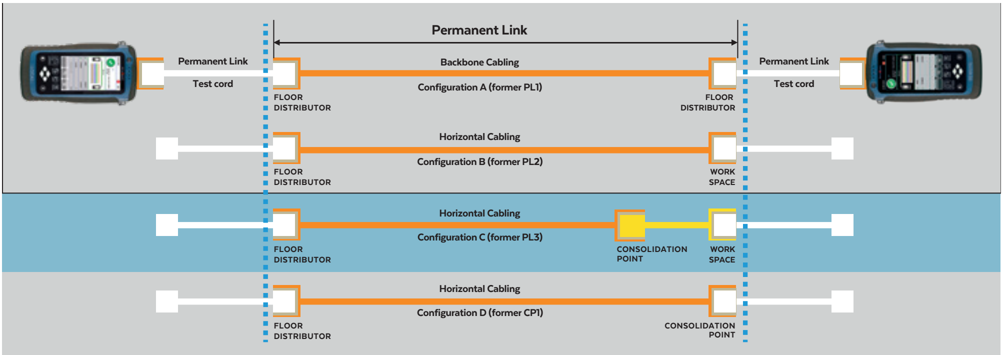


Figure 13b: Permanent link measurements according to ANSI/TIA 568.2.D; *Source: Softing IT Networks*

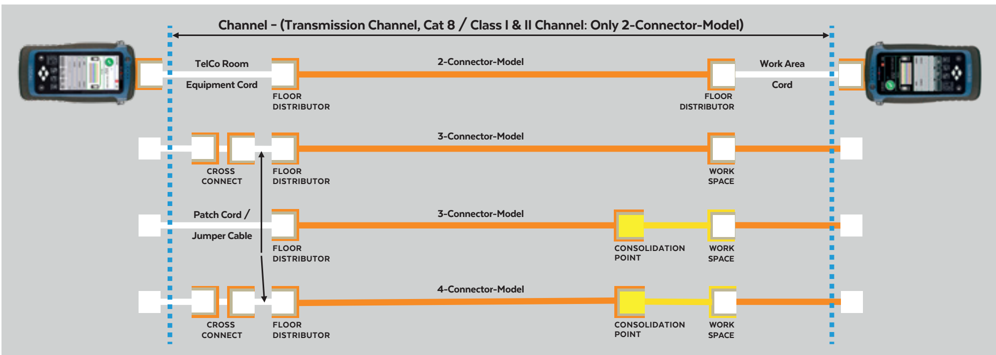


Figure 14: Channel (Transmission channel) measurement, Cross Connect – opt. additional distribution field i.e., in the Data Center; *Source: Softing IT Networks*

Apart from that, not much has changed in the measurement parameters; the properties of the cabling route (permanent link) are still measured and determined, as has been the case for a long time, as summarized in the textbox below.

Measurement parameters on cabling sections

- Wiring and shielding (Wiremap, Shield)
- Direct current resistance of the wire pairs (DC Resistance)
- Delay and delay difference (Delay and Delay Skew)
- Length of the measurement, informative for ISO/IEC 11801 & EN 50173-1, normative for ANSI/TIA 568.0-E

and the high-frequency measurements such as

- Attenuation of the wire pairs (Insertion Loss)
- Crosstalk attenuation between the wire pairs (NEXT Loss)
- Return Loss of the wire pairs
- Crosstalk of the wire pairs at the far end (FEXT Loss)

From this, further parameters are then calculated such as

- Attenuation to crosstalk ratio at near end (ACR-N) (not used in ANSI/TIA 568.2-D)
- Attenuation to crosstalk ratio at the far end (ACR-F – formerly known as ELFEXT)
- Power sum of the crosstalk attenuation (PSNEXT)
- Power sum of the attenuation to crosstalk ratio at the near end (PSACR-N)
- Power sum of the attenuation to crosstalk ratio at the far end (PSACR-F)

Another special feature is still occasionally found in data centers today: an intermediate distributor (CC: Cross Connect) to which active components are permanently wired.
This means that a technician does not patch directly to the active component, but to the intermediate distributor. In the following we will look at the various measurements in detail.

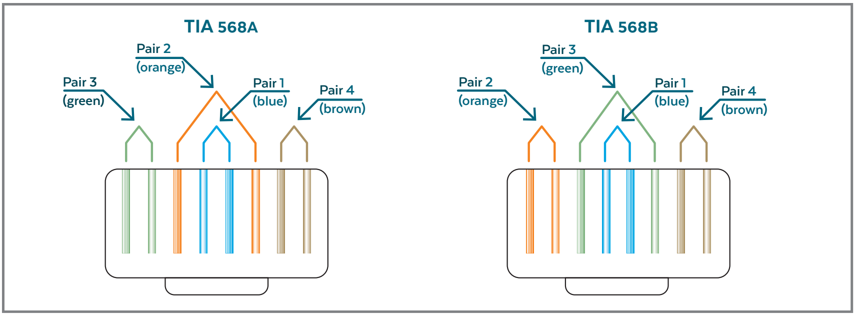


Figure 15: Pin assignments according to standard EIA/TIA-568A and EIA/TIA-568B, difference: pairs 2 and 3 reversed; *Source: Softing IT Networks*

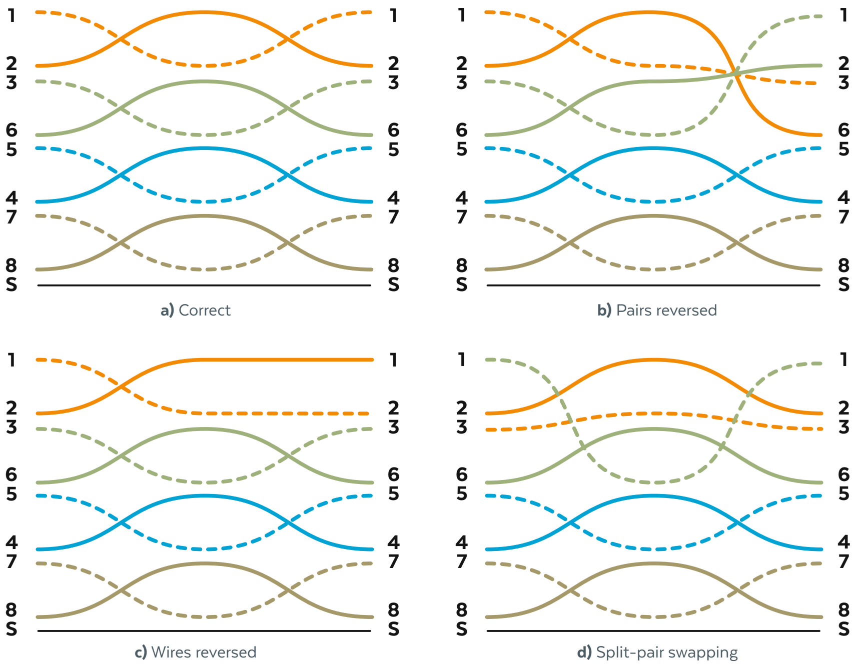


Figure 16: Wiring and faults: **a)** correct **b)** pairs reversed **c)** wires reversed **d)** Split-pair swapping (mutual swapping of two wires); *Source: Softing IT Networks*

IS THE WIRING (WIREMAP) CORRECT?

The proportion of wiring errors in installations is about 90% of all faulty links. When testing the wiring, the correct assignment of the wires and wire pairs from one end to the other of the wiring section is determined. Here, one can also see the type of connection according to EIA/TIA-568A or EIA/TIA-568B ***(see Figure 15)***. It is checked for correct continuity ***(see Figure 16a)*** of the individual wires, interruptions, short circuits (also to the shield), mix-ups of individual pairs ***(see Figure 16b)*** and wires ***(see Figure 16c)*** as well as for so-called split pairs ***(see Figure 16d)***.

Split pairs can happen by swapping e. g. 1 and 3 on both sides (in many cables these are the white wires). Some simple wiring testers (e. g. with LEDs), which only test for the passage of the wires, will not detect this error, because all wires, e. g. 1 to 1, 2 to 2, 3 to 3, etc. are still connected, but in this case the high-frequency test will detect an increased NEXT (near-end crosstalk) between the affected pairs.

One way to check the wiring for errors (including split pairs) is to use "smarter" wire mappers, such as the CableMaster 210, CableMaster 500, LinkXpert TP or LinkXpert M3 ***(see Figure 17)*** from Softing IT Networks.

Figure 17: CableMaster 210 / CableMaster 500 / LinkXpert TP / LinkXpert M3 cabling test device;
Source: Softing IT Networks

DC RESISTANCE OF THE WIRE PAIRS

The purpose of testing the DC resistance of the wire pairs is to check for poor contact between the wires when they are placed in the distribution panels, junction boxes or modules. For this purpose, the measuring instrument applies a defined current (a few mA) to the wire pairs, the end of the wire pairs is automatically short-circuited and the voltage drop at each wire pair is measured, which is then calculated using the formula

$$R = \frac{U}{I} [\Omega]$$

can calculate the resistance of the wire pairs in ohms (Ω = Omega). The measuring instruments then calculate the largest difference and output this as the result. The limit value of the wire pair resistance must not exceed 17.9 Ω for Permanent Link configurations A, B and D according to ISO/IEC 11801-1 / EN 50173-1 Classes D to FA and 4.4 Ω for Class I & II. The DC loop resistance limit from ANSI/TIA 568.2-D is 21 Ω for permanent links Cat 3 to 6A and 5.6 Ω for Cat 8.

R =Direct current resistance of a pair of wires

U = Voltage on the wire pair

I = Current in the wire pair

Ω = SI Unit for Ohm

DELAY AND DELAY SKEW

With the delay time measurement, the cabling certifier measures the time required for the signals to travel from one end to the other end of the cabling route. This value depends on the length of the cable route. However, the more important value here is the delay time difference (Delay Skew) since we use all four wire pairs simultaneously for transmission with transmission methods from 1Gb/s upwards. Therefore, in order to be able to combine the signals in the receiver to form a data stream again, the Delay Skew between the wire pairs should not be greater than 43ns for ANSI/TIA 568.2-D Cat 5e to Cat 6A and 13.3ns for Cat 8. For ISO/IEC 11801 the delay skew should be less than 43ns for Classes D to E_A, 25ns for Classes F and F_A, 14.2ns for Class I and 9ns for Class II.

DETERMINING THE CABLE LENGTH

Length measurement, as described above, is not required as PASS/FAIL criteria by all standards, but is usually used by installation companies for billing purposes. Therefore, all cabling certifiers today also measure the length of the cabling sections. The correct length measurement would have to be measured with a measuring tool – i. e. folding rule – that can be traced back to the original meter or today to the new definition of the meter. This is of course not easy if the cables are installed. Another option would be to read the length from the meter markings on the cables, but this is also somewhat complicated, so another method is needed. Measuring instruments can already measure the delay time of data from one end of the cable route to the other. From the result of the delay time measurement and the speed of the electrical signals in the cable, the length of the distance can be calculated.

The speed in the cable: Electromagnetic waves propagate at the speed of light in an absolute vacuum, but more slowly in all other media. To determine the length from the delay time and the speed in the medium, we need the so-called NVP factor (Nominal Velocity of Propagation = shortening factor). This can either be obtained from the cable manufacturer or determined with the cabling certifier at a known length, e. g. 40m.

If the proper NVP factor is entered in the cable definitions for the cabling to be measured as a parameter in the measuring device, then the lengths can be "measured" (calculated) by the device. The formula that is used is

$$l = t \times NVP \times c \ [m]$$

l = length of the cable section

t = simple running time

NVP = reduction factor

c = speed of light (299 792 458 m/s)

MEASUREMENTS OF THE HIGH FREQUENCY CHARACTERISTICS

The high-frequency characteristics of the four-pair transmission path determine its quality. To determine the quality of application-neutral communication cabling, the standards ANSI/TIA-1152-A / IEC 61935-1 proposes methods for measuring it. The standard ANSI/TIA 568.0-E / ISO/IEC 11801-x / EN 50173-x provides general information on the design of application-neutral communication systems, while the ANSI/TIA 568.0-E / ISO/IEC 14763-2 / EN 50174 series specifies rules for their installation and documentation.

ATTENUATION OF THE WIRE PAIRS

The high-frequency attenuation of the cabling section is measured in the frequency range of the corresponding cabling Class (e. g. Class E_A up to 500MHz) and depends on the length of the cables and the wire cross-section of the cables used. The attenuation of the wire pairs is the logarithmic ratio of the signal fed into the pairs and the signal arriving at the other end of the cable section ***(see Figure 18)***. The calculation is made according to the formula

$$IL(f) = 20 \times \log\left(\frac{U_O(f)}{U_I(f)}\right) \ [dB]$$

IL = Attenuation of pairs

U_O = Output voltage

U_I = Input voltage

dB = Decibel

and is expressed in decibels (dB). Of the four attenuations, the largest value is used to evaluate the cabling attenuation. Today's cabling certifiers also graphically display and store the measured values of all four wire pairs.

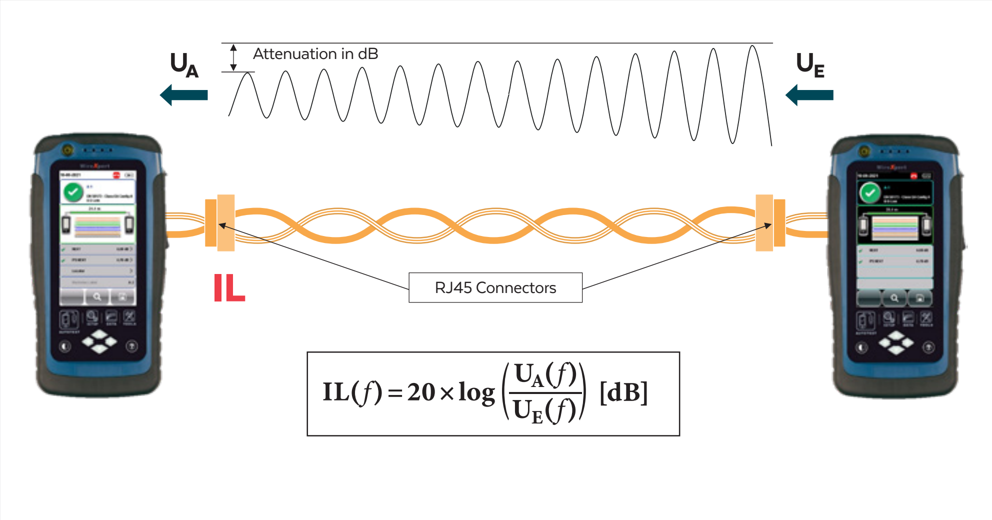


Figure 18: Attenuation measurement on a cabling link; *Source: Softing IT Networks*

CROSSTALK ATTENUATION BETWEEN THE WIRE PAIRS (NEXT)

Crosstalk from one pair of wires to another pair of wires is an undesirable effect, since the crosstalk causes interference on the other pairs, thus disturbing their signal transmission. The near-end crosstalk (crosstalk) of the cabling section is also measured in the corresponding frequency range and depends on the components used, the cables, and the processing when the cables are connected on the connection components.

Near End Crosstalk or NEXT (Near End X [Cross] Talk), it is the determination of how much of the signal is transmitted from a transmitting wire pair to an adjacent wire pair at the same (near) end where the transmitting signal is fed in ***(see Figure 19)***. With a four-pair cable, measurements would have to be made from each pair of wires to each of the other pairs of wires, which would mean 4 x (4 – 1) measurements for a four-pair cable, i. e. twelve measurements. However, since the measurement of e. g. pair 12 to pair 36 provides the same results as a measurement of pair 36 to pair 12, it was agreed to perform only six measurements. However, since the effect of crosstalk can only be detected about 40 – 50m into the pairs, these measurements have to be performed from both sides of the cable

NEXT = Near End X(Cross) Talk = near end crosstalk attenuation
U_A = Output voltage
U_E = Input voltage
dB = Decibel

section, resulting in a total of twelve NEXT curves. The calculation of the near-end crosstalk attenuation is based on the formula

$$NEXT(f) = 20 \times \log\left(\frac{U_O(f)}{U_I(f)}\right) \quad [dB]$$

and is also expressed in dB. Of the measured values, the smallest distance from the limit value curve is used as the worst value for evaluating the cabling section. The total measured values of all pair combinations are also graphically displayed and stored.

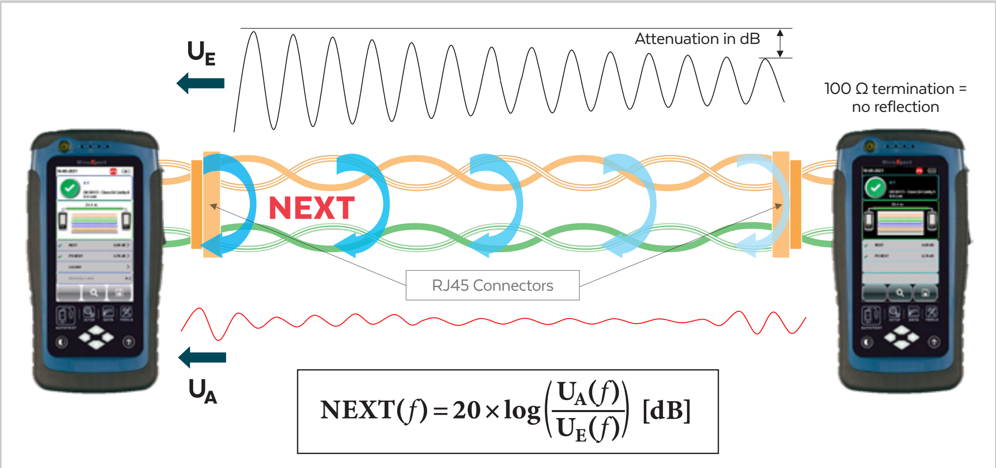


Figure 19: Principle of crosstalk attenuation (NEXT); *Source: Softing IT Networks*

RETURN LOSS OF THE PAIRS

The return loss is a measurement of the uniformity of the impedance in the cabling section and is also one of the undesirable characteristics since the reflected signal interferes with the signal transmission on the wire pairs themselves. The measurement principle for this is shown in ***Figure 20***. The high-frequency return loss of the cabling section is also measured here in the frequency range of the corresponding cabling Category/Class and depends on the components and cables used and the processing when the cables are connected to the connection components. In the return loss measurement, the reflected signal amplitude U_O is determined as a function of the fed-in signal U_I on the same wire pair.

However, since the effect of reflection also only affects the wire pairs up to about 40 – 50m, these measurements must also be carried out from both sides of the cabling section. This results in eight measurement curves for each cabling section.

The return loss is calculated according to the formula

$$RL(f) = 20 \times \log\left(\frac{U_O(f)}{U_I(f)}\right) \quad [dB]$$

RL = Return Loss
U_O = Output voltage
U_I = Input voltage
dB = Decibel

and is also expressed in dB. Of the measured values, the smallest distance to the limit curve of all traces is used as the worst value for evaluating the cabling. The total measured values of all pairs are also graphically displayed and stored.

CROSSTALK OF THE WIRE PAIRS AT THE FAR END (FEXT LOSS)

Crosstalk from pairs at the far end of the cabling route to the adjacent pairs is also an undesirable effect since this crosstalk also causes interference in 4-pair transmissions (1/2.5/5/10/40Gb/s). The high-frequency crosstalk of the cabling link is also measured in the frequency range of the corresponding cabling Class (e. g. Class E_A from 1 – 500 MHz) and is highly dependent on the components and cables used (e. g. UTP / S/STP) and the processing when the cables are connected to the connection components.

These interference events are called Far End X(Cross) Talk (FEXT). ***Figure 21*** shows the test setup for this purpose. In the case of a four-pair cable, measurements must be made from each pair at each end of the cabling section to each of the other pairs at the other end of the cabling, i. e. in the case of a four-pair cable and measurements on both sides 2 x 4 x (4 – 1) measurements, a total of 24 measurements.

The FEXT crosstalk attenuation is calculated according to the formula

$$FEXT(f) = 20 \times \log\left(\frac{U_O(f)}{U_I(f)}\right) \quad [dB]$$

FEXT (*f*) = Far-End X [Cross] Talk attenuation
U_O = Output voltage
U_I = Input voltage
dB = Decibel

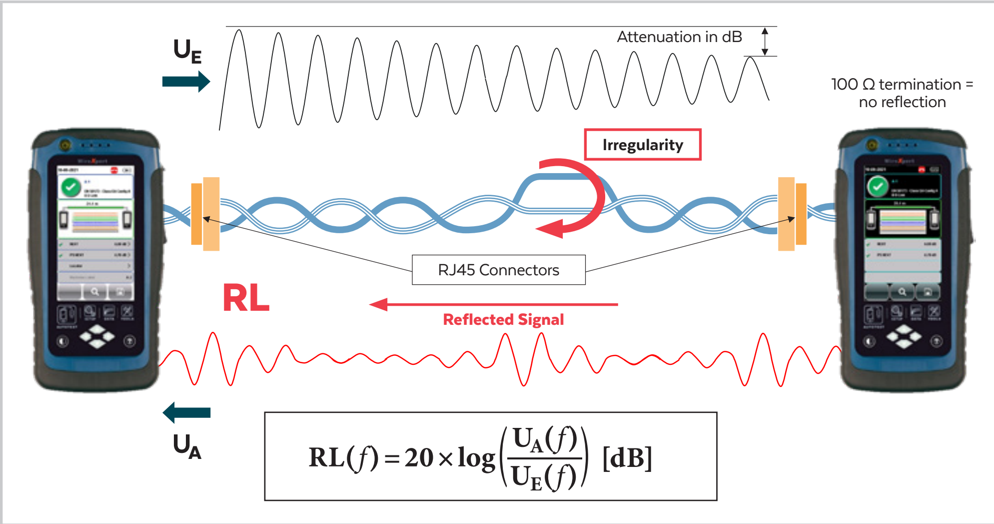


Figure 20: Return loss, also known as reflection loss, measurement method; *Source: Softing IT Networks*

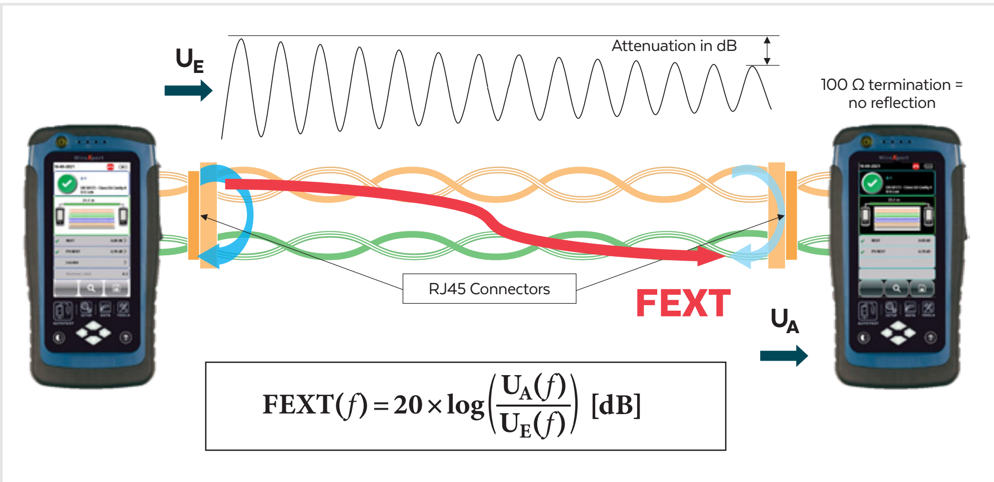


Figure 21: Crosstalk of pairs at the far end (FEXT Loss); *Source: Softing IT Networks*

However, the FEXT values determined in this way are not meaningful on their own and therefore not suitable for limit value comparisons, since the FEXT results are directly dependent on the length (attenuation) of the cabling route. Therefore, a comparable result is generated from these measured values by calculation (see ACR-F).

With this we have described all high frequency measurement parameters that are measured during the execution of an Autotest with a cabling certifier. However, since some of the measurement results described so far do not by themselves describe all the interference events that occur during transmission over a cabling section, a few more results must be calculated from these measured high-frequency parameters. We describe these calculated results in the following.

ATTENUATION TO CROSSTALK RATIO AT NEAR END

To obtain a statement about the useful signal to interference signal ratio of a cabling section, the attenuation (useful signal) to crosstalk (interference signal) ratio (ACR-N, Attenuation Cross Talk Ratio – Near End) is calculated at the near end of the cabling section ***(see Figure 22)***. This is calculated from the attenuation measurement results already measured and the near-end cross talk measurement results at the near end of the cabling section using the following formula

$$\mathrm{ACR\text{-}N}(f) = \mathrm{NEXT}(f) - \mathrm{ATTENUATION}(f) \quad [\mathrm{dB}]$$

As with NEXT, twelve results are then obtained, since these are calculated from the twelve NEXT measurement results measured from the near and far end of the cabling sections and the attenuation measurement results of the disturbed pairs. These twelve ACR-N results are also graphically represented by the cabling certifier.

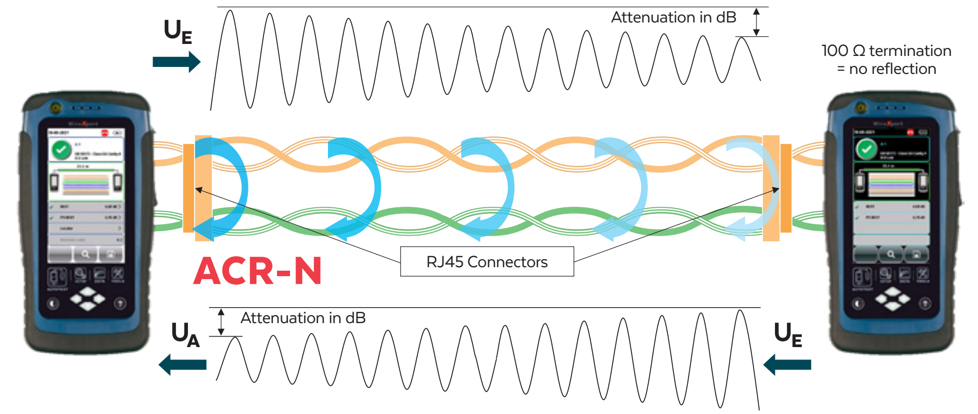
Note: This result is only required for ISO and CENELEC, but not for ANSI/TIA standards.

ACR-N = Attenuation to Near End Crosstalk Attenuation Ratio

NEXT = Near End X (Cross) Talk Attenuation

ATTENUATION = Attenuation on a pair of wires

dB = Decibel



$$ACR\text{-}N(f) = NEXT(f) - ATTENUATION(f) \quad [dB]$$

Figure 22: Attenuation to crosstalk ratio at the near end (ACR-N); *Source: Softing IT Networks*

ATTENUATION TO CROSSTALK RATIO AT THE FAR END

Previously, this attenuation to crosstalk ratio was referred to as ELFEXT (Equal Level Far End X [Cross] Talk), in the more recent versions of the standards it is now referred to as ACR-F.
To obtain comparable results to limit curves from the measured 24 FEXT measurement results from the near and far end of the cabling section, the attenuation belonging to the disturbed pairs must be subtracted from each of the measured FEXT values of the disturbed pairs *(see Figure 23)*. The measuring instrument calculates the ACR-F results with the following formula

$$ACR\text{-}F(f) = FEXT(f) - Attenuation(f) \quad [dB]$$

By calculating the ACR-F results, these values are then comparable with the limit values, since the length-dependent component (Attenuation) is subtracted from the FEXT values, which is also dependent on length. These 24 ACR-F results are usually also displayed graphically for all common certifiers.

ACR-F = Attenuation to Cross Talk Ratio – Far End

FEXT = Far End X (Cross) Talk = Far End Cross Talk Attenuation

ATTENUATION = Attenuation of pairs

dB = Decibel

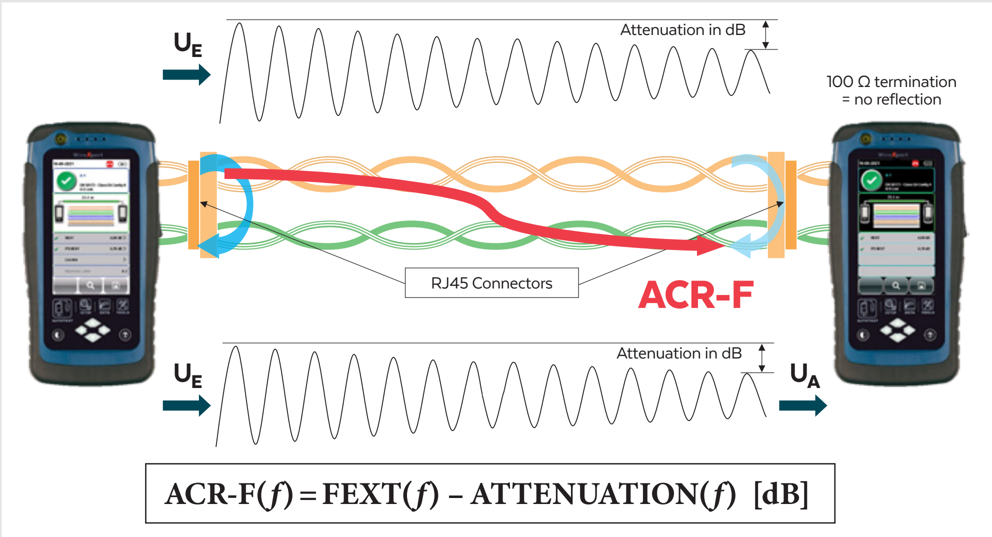


Figure 23: Attenuation to Crosstalk ratio at the far end (ACR-F, formerly ELFEXT); *Source: Softing IT Networks*

POWER SUM RESULTS

The power sum results are important for all 4-pair transmission methods (1/2.5/5/10/25/40Gb/s), since signals are transmitted simultaneously over all 4 wire pairs, which can interfere with each other. With the power sum results, one considers the mathematical summed interference of three interfering wire pairs on a fourth wire pair ***(see Figure 24*** – Example PSNEXT). These power sums are also calculated results from the measured values, such as NEXT, or from already calculated values, such as ACR-N or ACR-F, using the following formulas

$$PSNEXT_k(f) = -10 \times \log\left(\Sigma_{i=1,\, i\neq k}^{n} 10^{-0,1 \times NEXT(f)i,k}\right) \quad [dB]$$

Similarly, the same formula is used to calculate the power sum values for ACR-N and ACR-F.

$PSNEXT_k$ = Power Sum NEXT = power summed near-end cross-talk attenuation of the disturbed pair k

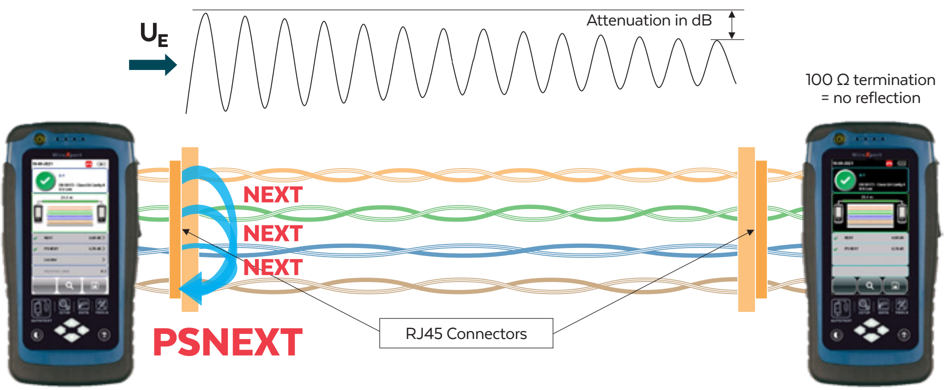
$NEXT_{i,k}$ = Near-end crosstalk attenuation from pair i to pair k

dB = Decibel

Errors in the power sum values are always due to the underlying parameters, i. e.

- PSNEXT errors are caused by NEXT errors
- PSACR-N errors have their cause in the ACR-N
  ACR-N errors are again due to attenuation and/or NEXT
- PSACR-F errors have their cause in the ACR-F
  ACR-F errors are again due to attenuation and/or FEXT (NEXT)

This would now describe all the parameters that a certifier determines or calculates during a test in just a few seconds. The certifier then compares these determined or calculated results with the limit values or limit value curves of the corresponding standards ***(see Figures 10 to 12)***. The WireXpert 4500 certifier requires just 10 seconds for a Cat 6A / Class E_A Autotest and only 22 seconds for a Class F/F_A, Cat 8, Class I or II Autotest, measured up to a frequency of 2000MHz.



$$PSNEXT_k(f) = -10 \times \log(\Sigma_{i=1, i\neq k}^{n} 10^{-0,1 \times NEXT(f)i,k}) \quad [dB]$$

Figure 24: Power Sum, power sum measurement; *Source: Softing IT Networks*

CHAPTER 4:

DOCUMENTATION

DOCUMENTATION OF MEASUREMENT RESULTS

After installation and acceptance measurements, the measurement results are documented.

Certification is a test of compliance with certain standards for products/services and their respective manufacturing processes by issuing a certificate. A cabling certifier is responsible for checking the cabling sections for conformity to the relevant standards. The results can be a summary of all the individual tests of an Autotest into an overall evaluation as PASS or FAIL and saved in a report. With modern equipment capable of performing Autotests according to Class E_A, F/F_A, CAT 8, Class I and Class II (the latter up to 2000MHz) and storing them with all graphical results, up to 190 000 data points are stored per Autotest. Today's cabling certifiers must be able to store thousands of these Autotests including all data points.

The creation of certificates with their graphics is done by the provided evaluation software, eXport, by transferring the complete results of the Autotests to the evaluation software via USB stick or by direct connection to a PC via Mini-USB cable. With the help of this software, the results can then be sorted, grouped and thus certificates can be generated for each individual Autotest, either as a summary report ***(see Figure 25)*** or as an individual report ***(see Figure 26)***. The summary reports and individual reports are then handed over to the customer after completion of a project. As a rule, the installation company then uses the summary report with the sum of all measured lengths to create the invoice for the corresponding project.

The certifications of the cabling links carried out are then also used by the installation companies to obtain a system guarantee for the cabling project. To do this, the installation company sends the measurement results as raw data or as PDF files (depending on what the manufacturers requires) to the cabling system manufacturer. The manufacturer in turn then issues a system warranty for 15, 20 or even more years.

Summary Report

softing

Cable Label	Limit	Result	Length (m)	Margin (dB)	Date & Time
8.2 24+2-2m channel	TIA - Cat 8 Channel 22-23AWG	✔	31,1	13,8	31/10/2016 11:43:04 PM
B-40	ISO 14763-3	✔	3,1	0,48	03/11/2016 04:57:16 PM
1A-A2	TIA - Cat 6A Channel	✔	98,6	7,7	17/11/2016 01:52:03 PM
1A-B2	ISO - Class FA Channel	✔	57,2	6,5	17/11/2016 03:03:46 PM
A-11	TIA-PatchCord Cat6 2m	✔	3	4	18/11/2016 01:21:53 PM
A-23	ISO - Class D Link PL1 PL2 CP1	✔	17,5	13	18/11/2016 01:38:40 PM
A-5	40GBASE-SR4	✔	-	-	18/11/2016 02:26:05 PM
A-12	Link Validation	✔	-	-	23/11/2016 01:33:57 PM
E-18	TIA-568.3	✔	2,3	1,5	25/11/2016 04:06:26 PM
A-10	TIA-568.3	✔	244	0,5	30/11/2016 05:46:40 PM
A-12	TIA-568.3	✔	244	0,6	30/11/2016 06:15:03 PM

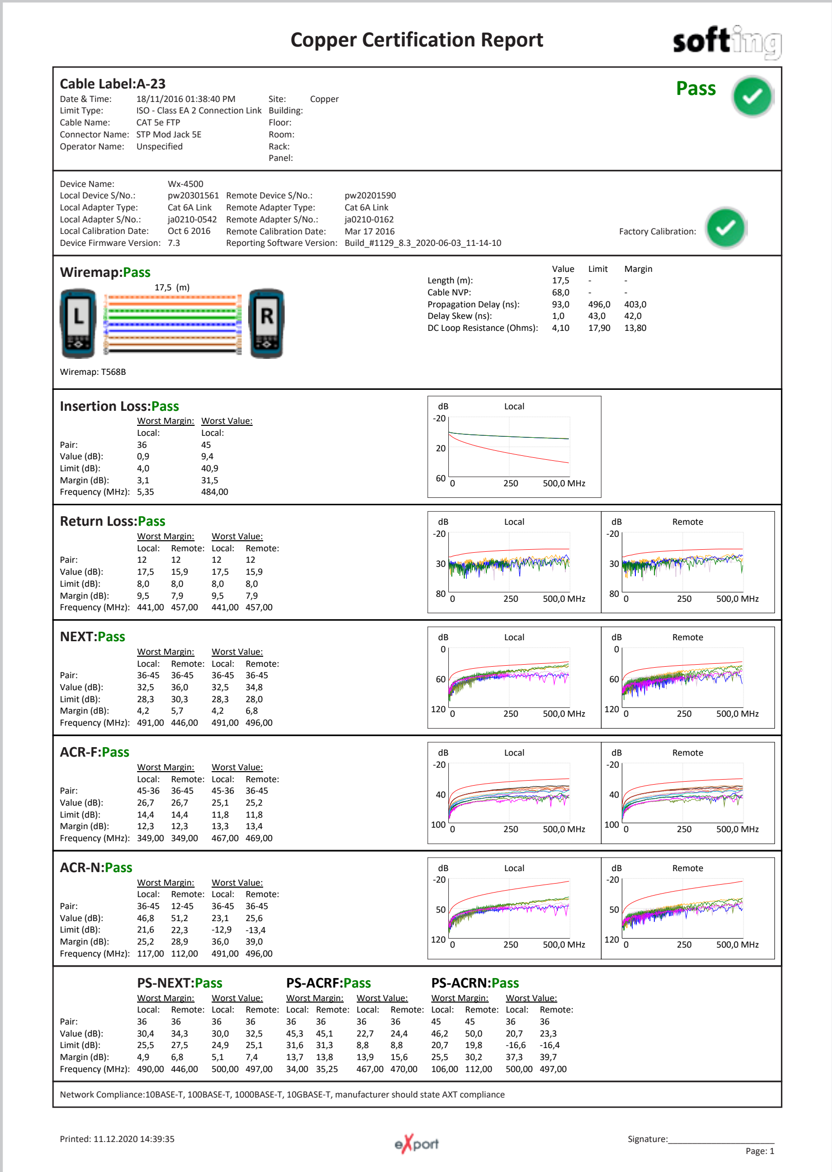
Total for Selected Reports	Pass	Fail	Length (m)
Copper	5	0	207,4
Fiber	4	0	493,4
MPO	1	0	0
Power Meter	1	0	0

Printed: 11.12.2020 14:20:29 eXport Signature:____________________

Figure 25: Summary report of an acceptance measurement of a data cabling

This system warranty, which then applies to the cabling project in question, enables the network owner to contact the system manufacturer if a malfunction occurs during the term of the system warranty that is due to a problem in the cabling system.

This gives the owner of the network a protection of his investment that goes beyond the usual warranty claim of the installation company. At the same time, the installation company has also made a clean finish to a cabling project, i. e. if a problem arises at the customer's premises after the project has been handed over by means of the protocols, the installer can also refer to these protocols and exclude liability and warranty.



Copper Certification Report

softing

Cable Label:A-23 — **Pass**

Date & Time:	18/11/2016 01:38:40 PM	Site:	Copper
Limit Type:	ISO - Class EA 2 Connection Link	Building:	
Cable Name:	CAT 5e FTP	Floor:	
Connector Name:	STP Mod Jack 5E	Room:	
Operator Name:	Unspecified	Rack:	
		Panel:	

Device Name:	Wx-4500		
Local Device S/No.:	pw20301561	Remote Device S/No.:	pw20201590
Local Adapter Type:	Cat 6A Link	Remote Adapter Type:	Cat 6A Link
Local Adapter S/No.:	ja0210-0542	Remote Adapter S/No.:	ja0210-0162
Local Calibration Date:	Oct 6 2016	Remote Calibration Date:	Mar 17 2016
Device Firmware Version:	7.3	Reporting Software Version:	Build_#1129_8.3_2020-06-03_11-14-10

Factory Calibration: ✓

Wiremap:Pass

17,5 (m)

Wiremap: T568B

	Value	Limit	Margin
Length (m):	17,5	-	-
Cable NVP:	68,0	-	-
Propagation Delay (ns):	93,0	496,0	403,0
Delay Skew (ns):	1,0	43,0	42,0
DC Loop Resistance (Ohms):	4,10	17,90	13,80

Insertion Loss:Pass

	Worst Margin: Local:	Worst Value: Local:
Pair:	36	45
Value (dB):	0,9	9,4
Limit (dB):	4,0	40,9
Margin (dB):	3,1	31,5
Frequency (MHz):	5,35	484,00

Return Loss:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	12	12	12	12
Value (dB):	17,5	15,9	17,5	15,9
Limit (dB):	8,0	8,0	8,0	8,0
Margin (dB):	9,5	7,9	9,5	7,9
Frequency (MHz):	441,00	457,00	441,00	457,00

NEXT:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	36-45	36-45	36-45	36-45
Value (dB):	32,5	36,0	32,5	34,8
Limit (dB):	28,3	30,3	28,3	28,0
Margin (dB):	4,2	5,7	4,2	6,8
Frequency (MHz):	491,00	446,00	491,00	496,00

ACR-F:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	45-36	36-45	45-36	36-45
Value (dB):	26,7	26,7	25,1	25,2
Limit (dB):	14,4	14,4	11,8	11,8
Margin (dB):	12,3	12,3	13,3	13,4
Frequency (MHz):	349,00	349,00	467,00	469,00

ACR-N:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	36-45	12-45	36-45	36-45
Value (dB):	46,8	51,2	23,1	25,6
Limit (dB):	21,6	22,3	-12,9	-13,4
Margin (dB):	25,2	28,9	36,0	39,0
Frequency (MHz):	117,00	112,00	491,00	496,00

PS-NEXT:Pass / **PS-ACRF:Pass** / **PS-ACRN:Pass**

	PS-NEXT Worst Margin: Local:	Remote:	PS-NEXT Worst Value: Local:	Remote:	PS-ACRF Worst Margin: Local:	Remote:	PS-ACRF Worst Value: Local:	Remote:	PS-ACRN Worst Margin: Local:	Remote:	PS-ACRN Worst Value: Local:	Remote:
Pair:	36	36	36	36	36	36	36	36	45	45	36	36
Value (dB):	30,4	34,3	30,0	32,5	45,3	45,1	22,7	24,4	46,2	50,0	20,7	23,3
Limit (dB):	25,5	27,5	24,9	25,1	31,6	31,3	8,8	8,8	20,7	19,8	-16,6	-16,4
Margin (dB):	4,9	6,8	5,1	7,4	13,7	13,8	13,9	15,6	25,5	30,2	37,3	39,7
Frequency (MHz):	490,00	446,00	500,00	497,00	34,00	35,25	467,00	470,00	106,00	112,00	500,00	497,00

Network Compliance:10BASE-T, 100BASE-T, 1000BASE-T, 10GBASE-T, manufacturer should state AXT compliance

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Page: 1

Figure 26: PDF document of a cable certification, graphical evaluations of all measured and (most) calculated parameters

CHAPTER 5:

TROUBLESHOOTING

TROUBLESHOOTING IN DATA NETWORKS

In connection with the certification of a data cabling, a fault diagnosis can be done in case of an existing fault (deviation from the standard). We describe some typical cases of errors here.

"In the unlikely event of a pressure loss in the cabin, the air masks will automatically ...". This sentence is probably familiar to those who have already been flying once or several times. But luckily only very few of us have experienced it because this case is very unlikely.

In the case of a cabling certification, the occurrence of errors is unfortunately much more likely. Approximately 5% of all installed cabling lines initially have errors after an installation, but of these, as mentioned above, approximately 90% are cabling or wiring errors. Let us now turn to a description of the error and troubleshooting in detail.

WRONG WIRING, WRONG TERMINATION OF CONNECTING HARDWARE

We have already described wiring errors ***(see Figure 16)***, including the variants. ***Figure 27*** shows a typical wiring error that a wiring certifier would indicate. This case is clear, the orange wire (pin 6) of wire pair 36 is interrupted after approx. 40m, so the installer can locate and correct this error.

With crossed wires or pairs of wires this is unfortunately somewhat more difficult. No cabling certifier in the world can indicate on which side a wire or wire pair crossover has occurred, so it only helps to open the connection component on one side of the cabling section to check the wiring. According to Murphy's Laws the connection component that is opened first is usually OK and by that it is discovered that the fault must be at the other end of the wiring path (quote – Murphy's Laws: "What you are looking for, you will always find in the place where you last looked." *Source: Internet*). In general, however, most wiring errors can be corrected without much effort.

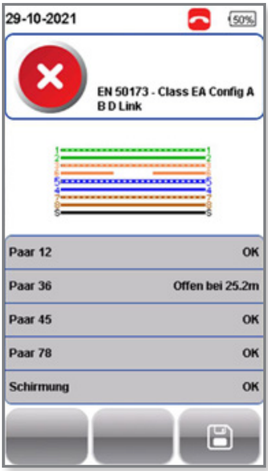


Figure 27: Typical wiring error; *Source: Softing IT Networks*

DIRECT CURRENT (DC) RESISTANCE ERRORS

In terms of measurement technology, these faults can usually be limited to affected pair of wires. The reasons for this can be:

- A poor connection due to insufficient cutting of the IDCs (Insulation Displacement Contacts) into the wires. This occurs less frequently today, as connection techniques have improved considerably over the last few years.
- A bad connection due to external contamination of the connectors. This cause can usually be easily identified and eliminated by cleaning the connectors.
- An overlength of the cabling route, this error can only be corrected by a shorter installation route, but this should not happen with good planning and execution.

However, if a DC resistance error is present, the cause can usually also be determined during the attenuation and return loss measurement and localized with a Time Domain Return Loss (TDRL) measurement.

DELAY AND DELAY SKEW ERRORS

Delay and delay skew errors should actually no longer occur today, since only an excess length of the cabling route can be the cause of this error. So if such an error occurs, always first look at the cable length to see if this is the cause of the error.

There is one more exception, but it is extremely rare nowadays, that would be production errors when twisting the wire pairs during production.

The situation is different when the errors become more complex. In the case of high-frequency measurements, the installation or connection methods, among other things, can be the cause of further errors.

However, errors due to insufficient accuracy of the cabling certifiers could also be the cause, which we will discuss again at the end of this section.

ATTENUATION ERROR

Attenuation errors can also have various reasons:

- An overlength of the cabling section, the solution would be a shorter cable or other installation route,
- A poor connection, either on the insulation displacement contacts or contact side of the plug connections (dirt or wire breakage), see also DC resistance error,
- By using a cable with a core diameter that is too small, e. g. cable with AWG 26 (American Wire Gauge, coding for wire diameter), which would be due to a planning error and can only be solved by replacing the cable sections.

Another, rather rare reason for attenuation errors could also be too high signal reflection, which would then also be noticeable in the return loss measurement.

CROSSTALK IN DATA CABLES

Crosstalk attenuation errors can also have various reasons:

- Excessive removal of the wire pair shielding foils during installation, especially for higher transmission Classes from Class E_A and higher, in this case only cutting off the cable and re-connecting it is helpful.
- Excessive untwisting of the wire pairs during installation, this is an installation error. The only thing that helps here is to cut off the cable and reconnect it.
- Incorrect components, e. g. Cat 5e connection components instead of Cat 6A/Cat 6A components, but this would also be more likely to fall into the group of planning errors and could only be rectified by installing new connection components (with different parameters).
- Incorrect measurements, if you have installed CAT 5e/Class D cabling sections and then try to perform a Class E_A measurement. This then falls into the group of operating errors of the cabling certifier.
- Wrong measurement setup, if the measurement technician tries to perform a Channel Link measurement with inferior patch cables (patch cables not corresponding to the present category), this would again be interpreted as an operating error.

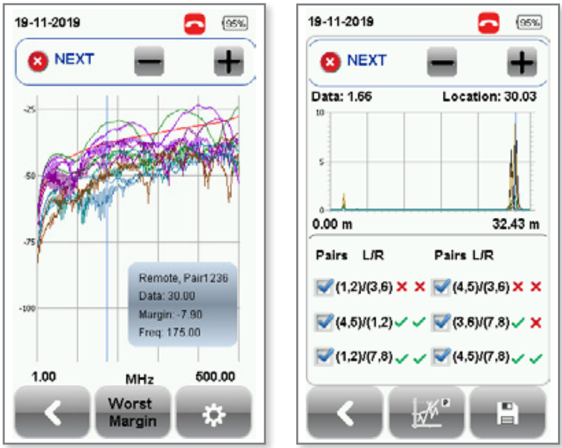


Figure 28: Left: NEXT failure, right: Time domain calculation, localization of the failure in the cable run; *Source: Softing IT Networks*

In addition to the high-frequency representations of NEXT ***(see Figure 28 left)***, modern cabling certifiers can display NEXT over the length of the cabling path for troubleshooting purposes; for most devices this is called "Time Domain NEXT" ***(see Figure 28 right)***. With the help of this display, the location of the NEXT errors can be located, i. e. distance information of the location of the increased NEXT is obtained.

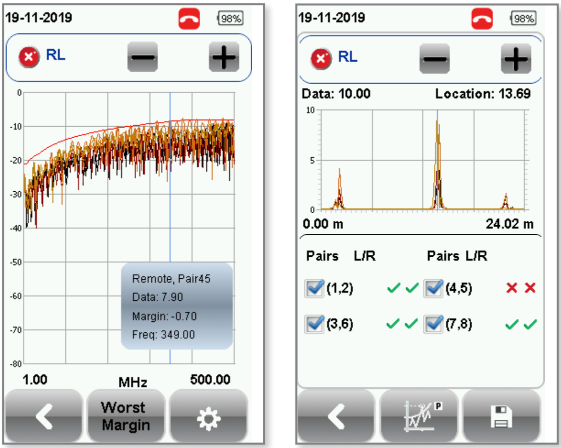


Figure 29: Left: Return loss error detected, right: time-domain measurement, localization of the error location in the cable; *Source: Softing IT Networks*

RETURN LOSS ERROR

Return loss errors can also have various reasons:

- Too much untwisting of the twist of the wire pairs during installation, this is a clear installation error and here again only cutting off the cable and re-connecting it to the connector will help.
- Excessive stretching of the cable during pulling. Although installers should not “pull” the cable, but “insert” it. “Pulling” is incorrectly the common practice. This can cause a cable to be overstretched, resulting in a change in cable impedance due to the stretching, and a return loss error. Then the only thing that helps is to replace the entire cable.
- Incorrect components, e. g. Cat 5 instead of Cat 6A/Cat 6_A connectors, but this would also be more likely to belong to the group of planning errors.
- Incorrect measurements, if you have installed Class E_A cabling and try to carry out a Class F or F_A measurements, this then falls into the group of planning errors or operating errors of the cabling certifier.
- Wrong measurement setup, if the measurement technician tries to perform a channel measurement with inferior patch cables, this falls into the group of operating errors.
- Poor connection, either on the insulation displacement or contact side of the connectors, see also DC Resistance error.

Figure 30: Left: ACR-N error, center: Attenuation, Right: Crosstalk attenuation; *Source: Softing IT Networks*

In addition to the high-frequency displays of the measurement results ***(see Figure 29 left)***, the return loss measurement also includes the so-called time domain return loss display ***(see Figure 29 right)*** for troubleshooting purposes.

With the aid of this display, return loss errors can be located, i. e. distance information from the location of the measuring instrument to the point of increased reflection is displayed.

Errors can also be displayed in the calculated measurement results, so we will also discuss these.

ACR-N & ACR-F ERRORS

ACR-N errors (attenuation to crosstalk ratio at the near end) occur only if one or both of the measured parameters are incorrect. Therefore – if such an error occurs ***(see Figure 30 left)*** – the installer must look at the underlying parameters, Attenuation ***(see Figure 30 middle)*** and NEXT (crosstalk attenuation, ***see Figure 30 right)*** and search for the errors there.

ACR-F errors (attenuation to crosstalk ratio at the far end) are caused either by too much attenuation of the affected wire pair or by too much FEXT (crosstalk of the wire pairs at the far end). If the Attenuation is the cause, then there may be something that can be saved, see Attenuation errors. But if the Attenuation is not faulty, then the FEXT is the cause, and the installer should contact the manufacturer of the cabling system because FEXT can occur either in the connection components or in the cable.

Power sum errors for PSNEXT (power sum of crosstalk attenuations [NEXT]), PSACR-N (power sum of attenuations to crosstalk ratios at the near end [ACR-N]) and PSACR-F (power sum of attenuations to crosstalk ratios at the far end [ACR-F]) do not occur in isolation, because all power sums are based on calculation from the measured parameters, so one must look at the underlying measurement or calculation parameters.

IT'S THE ACCURACY THAT COUNTS

At this point, we would also like to take a brief look at the measurement accuracy of cabling certifiers ***(see Figure 31)***. As already described above, this is a measuring device and is subject to certain tolerances – like all other measuring devices. However, since a cabling certifier is a multi-parameter measuring device, there are also different tolerance limits for the different measuring methods and measurement types. These are internationally standardized in a standard for laboratory and field measurement technology (IEC 61935-1) for both cabling certifiers and laboratory measuring instruments. A distinction is made between different accuracy levels, e. g. Level V accuracy is sufficient to measure Class F_A cabling sections.

Even higher accuracy levels are required for the measurement of Cat 8, Class I & II cabling sections, so there is already talk of proposals for level 2G accuracy for measurements up to 2000MHz. However, it should not be forgotten that the standards generally represent the agreement of the various members on the least common evil and that the measuring instruments are usually much more accurate in practice ***(see Figure 32)***. It is also important to have the cabling certifiers checked for accuracy at the Factory Calibration intervals specified by the manufacturers, so that installers are not surprised at some point in time by the fact that the device no longer measures as accurately as the manufacturer once stated. Recognizing this requires trained personnel who are familiar with the settings and parameters of a cabling certification. Furthermore, installers should well know about the described standards and measurement parameters, as well as error descriptions.

Figure 31: Cabling certifier, for example the WireXpert from Softing IT Networks; *Source: Softing IT Networks*

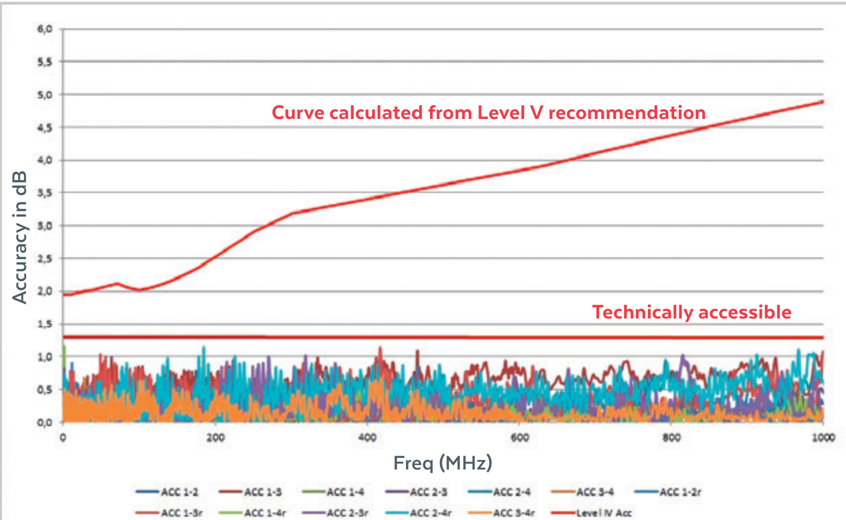


Figure 32: NEXT accuracy, achievable values and measured values; *Source: Softing IT Networks*

CHAPTER 6:

PATCH CORDS AND OTHER SPECIAL CASES

MEASUREMENT TECHNOLOGY FOR PATCH CORDS

In order to put structured cabling into operation, in addition to the installed cabling sections (Permanent Link) and the active components (Switch and NIC = Network Interface Card), you also need the ability to connect them to each other. This is usually done with patch cords. But how do you determine whether these patch cables match the transmission Class of structured cabling so that the entire transmission channel corresponds to the correct Class?

What is a patch cord?

A patch cable consists of an unshielded or shielded, flexible stranded cord and unshielded or shielded connectors connected to it at both ends. The usual lengths for patch cords range from 0.5m to 5m (or sometimes 10m or more). The still most common connector is again the RJ45 connector. This immediately reveals a problem: An RJ45 connector can only accept cords up to a certain sheath diameter.

This means that the cable thickness must be kept to a minimum, especially with shielded patch cords. This allows the use of core cross sections up to AWG 24 (American Wire Gauge ***see table 8)*** for unshielded patch cords. For shielded patch cords, especially for S/STP patch cords, mostly wires with cross sections of AWG 26 – AWG 27 are used. The term AWG refers to a standardized wire thickness of data cables.

Here, the numbers such as “24” mean the number of drawing operations during wire production. With an increasing number of successive drawing operations, a thinner wire diameter is achieved. Flexible data cables have approximately 20% higher attenuation. Another reason for higher attenuation is the structure of the shielded patch cables, through the shield. Due to the shielding foils, which are tightly attached to the pairs of wires, the capacity of the wires to ground potential is higher than in unshielded cables, which leads to an increase in attenuation of up to 50%. Due to this higher attenuation, the usable length of shielded patch cords is shortened even further compared to unshielded patch cords.

AWG	Diameter		Cross Sectional Area		R	Metric Equivalent
	inch	mm	kcmil	mm²	(Ω/km)	(mm²)
20	0.032	0.812	1.02	0.518	34.4	0.75
21	0.0285	0.723		0.41	43.4	0.5
22	0.0254	0.644	0.64	0.326	54.7	0.34
23	0.0226	0.573		0.258	68.9	
24	0.0201	0.511	0.404	0.205	86.9	0.25
25	0.0179	0.455		0.162	110	
26	0.0159	0.405		0.129	138	0.14
27	0.0142	0.361		0.102	174	
28	0.0126	0.321		0.081	220	0.09
29	0.0113	0.286		0.0642	277	
30	0.01	0.255		0.051	349	

Table 8: Extract from the AWG (American Wire Gauge) table, marks the most common wire cross sections; *Source: Softing IT Networks*

How do you examine patch cords for their properties?

The measurement technology for patch cords challenges the manufacturers of measuring instruments. On one hand, usually there are short cable lengths (compared to the installed cabling lengths) and on the other hand, the instruments have to make a statement about the performance Category of the patch cords including the connectors at both ends. This now assumes that the patch cord measurement technique requires measurements from end to end of the patch cords, including the connectors at both ends ***(see Figure 33)***. For this purpose, the ANSI/TIA-568.2-D/IEC 61935-2 standards for patch cords require specially standardized reference jacks for the respective measurement category of Cat 5e, 6, 6A/6_A, in order to be able to perform these measurements.

However, this also means that the measurement technology for the different measurement Classes also requires corresponding measurement adapters for the RJ45 connector, since separate measurement sockets are defined for each measurement Class of Cat 5e, 6, 6A/6_A. In addition, the standards also define the limit values for the different lengths of the patch cords, i. e. for each category of patch cords, such as Cat 5e, 6 and 6A/6_A, different NEXT and Return Loss limit values must be applied according to the length.

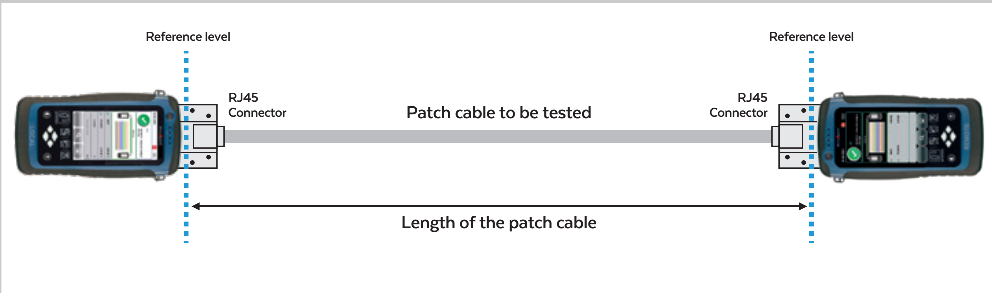


Figure 33: Test setup for patch cable measurements with the WireXpert; *Source: Softing IT Networks*

The measuring instruments provide this in the form of selectable limit values according to the category to be tested and the length of the patch cords ***(see Figures 34a & b)***. The corresponding reference planes are defined by the measuring instruments as soon as the measurement of patch cords is selected. If an Autotest ***(see Figure 35)*** is now carried out on the connected patch cords using the corresponding measurement adapters, a result is obtained within a few seconds (10s for Cat 5e, 6 and 6A/6_A) as to whether the tested patch cord corresponds to the set category. Then the measurement result can be stored in the measuring instrument and documented accordingly ***(see Figure 36)***.

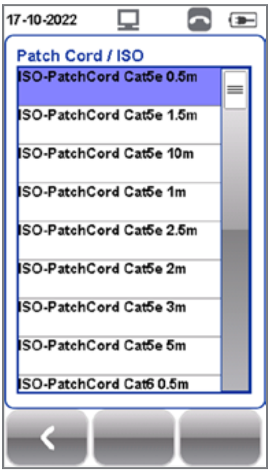


Figure 34a: Screenshot of the ISO PatchCord Limits selection for patch cables; *Source: Softing IT Networks*

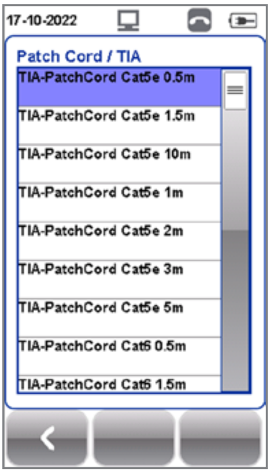
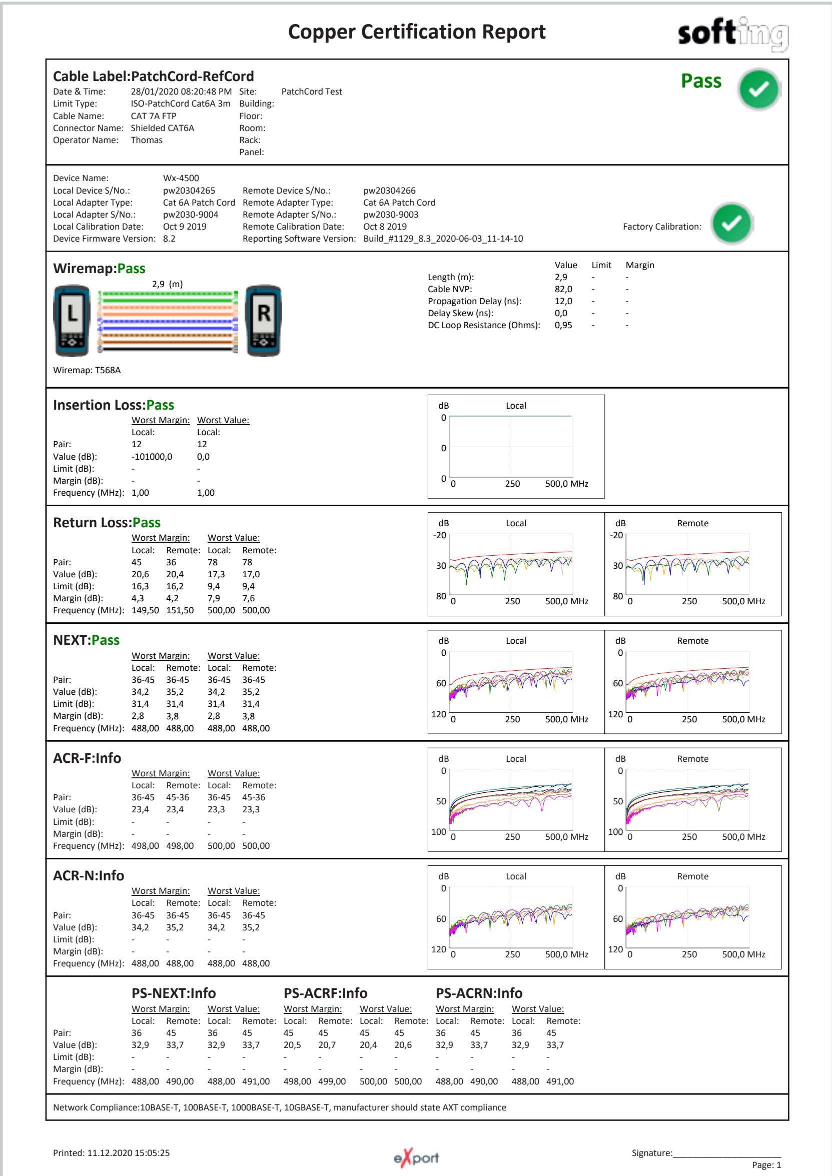


Figure 34b: Screenshot of the ANSI/TIA PatchCord Limits selection for patch cable; *Source: Softing IT Networks*



Copper Certification Report

Cable Label:PatchCord-RefCord — **Pass**

Date & Time:	28/01/2020 08:20:48 PM	Site:	PatchCord Test
Limit Type:	ISO-PatchCord Cat6A 3m	Building:	
Cable Name:	CAT 7A FTP	Floor:	
Connector Name:	Shielded CAT6A	Room:	
Operator Name:	Thomas	Rack:	
		Panel:	

Device Name:	Wx-4500		
Local Device S/No.:	pw20304265	Remote Device S/No.:	pw20304266
Local Adapter Type:	Cat 6A Patch Cord	Remote Adapter Type:	Cat 6A Patch Cord
Local Adapter S/No.:	pw2030-9004	Remote Adapter S/No.:	pw2030-9003
Local Calibration Date:	Oct 9 2019	Remote Calibration Date:	Oct 8 2019
Device Firmware Version:	8.2	Reporting Software Version:	Build_#1129_8.3_2020-06-03_11-14-10

Factory Calibration: ✓

Wiremap:Pass

2,9 (m)

Wiremap: T568A

	Value	Limit	Margin
Length (m):	2,9	-	-
Cable NVP:	82,0	-	-
Propagation Delay (ns):	12,0	-	-
Delay Skew (ns):	0,0	-	-
DC Loop Resistance (Ohms):	0,95	-	-

Insertion Loss:Pass

	Worst Margin: Local:	Worst Value: Local:
Pair:	12	12
Value (dB):	-101000,0	0,0
Limit (dB):	-	-
Margin (dB):	-	-
Frequency (MHz):	1,00	1,00

Return Loss:Pass

	Worst Margin: Local:	Worst Margin: Remote:	Worst Value: Local:	Worst Value: Remote:
Pair:	45	36	78	78
Value (dB):	20,6	20,4	17,3	17,0
Limit (dB):	16,3	16,2	9,4	9,4
Margin (dB):	4,3	4,2	7,9	7,6
Frequency (MHz):	149,50	151,50	500,00	500,00

NEXT:Pass

	Worst Margin: Local:	Worst Margin: Remote:	Worst Value: Local:	Worst Value: Remote:
Pair:	36-45	36-45	36-45	36-45
Value (dB):	34,2	35,2	34,2	35,2
Limit (dB):	31,4	31,4	31,4	31,4
Margin (dB):	2,8	3,8	2,8	3,8
Frequency (MHz):	488,00	488,00	488,00	488,00

ACR-F:Info

	Worst Margin: Local:	Worst Margin: Remote:	Worst Value: Local:	Worst Value: Remote:
Pair:	36-45	45-36	36-45	45-36
Value (dB):	23,4	23,4	23,3	23,3
Limit (dB):	-	-	-	-
Margin (dB):	-	-	-	-
Frequency (MHz):	498,00	498,00	500,00	500,00

ACR-N:Info

	Worst Margin: Local:	Worst Margin: Remote:	Worst Value: Local:	Worst Value: Remote:
Pair:	36-45	36-45	36-45	36-45
Value (dB):	34,2	35,2	34,2	35,2
Limit (dB):	-	-	-	-
Margin (dB):	-	-	-	-
Frequency (MHz):	488,00	488,00	488,00	488,00

PS-NEXT:Info, **PS-ACRF:Info**, **PS-ACRN:Info**

	PS-NEXT Worst Margin: Local:	PS-NEXT Worst Margin: Remote:	PS-NEXT Worst Value: Local:	PS-NEXT Worst Value: Remote:	PS-ACRF Worst Margin: Local:	PS-ACRF Worst Margin: Remote:	PS-ACRF Worst Value: Local:	PS-ACRF Worst Value: Remote:	PS-ACRN Worst Margin: Local:	PS-ACRN Worst Margin: Remote:	PS-ACRN Worst Value: Local:	PS-ACRN Worst Value: Remote:
Pair:	36	45	36	45	45	45	45	45	36	45	36	45
Value (dB):	32,9	33,7	32,9	33,7	20,5	20,7	20,4	20,6	32,9	33,7	32,9	33,7
Limit (dB):	-	-	-	-	-	-	-	-	-	-	-	-
Margin (dB):	-	-	-	-	-	-	-	-	-	-	-	-
Frequency (MHz):	488,00	490,00	488,00	491,00	498,00	499,00	500,00	500,00	488,00	490,00	488,00	491,00

Network Compliance:10BASE-T, 100BASE-T, 1000BASE-T, 10GBASE-T, manufacturer should state AXT compliance

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Figure 35: Measurement report of a patch cable measurement; *Source: Softing IT Networks*

MEASUREMENT TECHNOLOGY FOR INDUSTRIAL CABLING

Industrial cabling is the so-called end-to-end cabling (E2E), which are used in automation technology ***(see Figure 36)***. Measurement technology for industrial cabling poses similar challenges to the measurement of patch cords, as it requires measurement of the end-to-end link. However, an aggravating factor is that when measuring M12 cabling, the measuring device cannot always be used to directly access the ends of the cabling sections. There are even cabling sections that have different connectors at both ends, such as an M12 plug at one end and an M12 jack or RJ45 plug or jack at the other end. Therefore, similar to the permanent link measurement, an E2E measuring adapter and the preLink® measuring cables are used, which can be adapted to the cabling sections to be measured with suitable measuring heads ***(see Figure 37)***.

With the aid of these measuring adapters and suitable measuring cables, it is possible to connect to cabling sections to be measured in automation technology and then carry out an end-to-end measurement, whereby the reference planes are then also automatically placed behind the respective end connectors (***see Figure 38)***. An Autotest carried out in this way then determines – according to the required cabling Class/Category – the measurement results of the end-to-end cabling and can thus be easily performed and documented ***(see Figure 39)***.

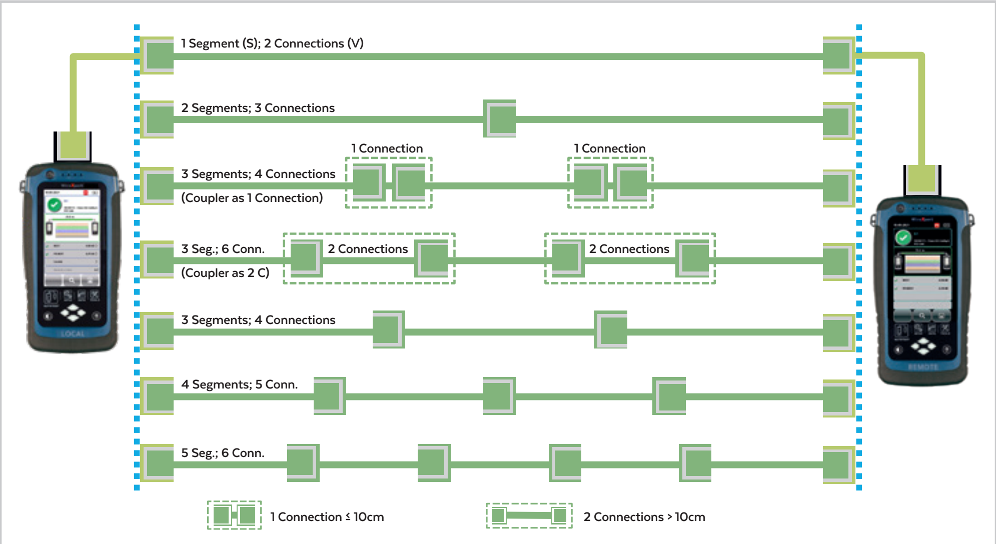


Figure 36: End-to-end cabling routes; *Source: Softing IT Networks*

Figure 37: E2E measuring adapters with Harting preLink measuring cables and various adapters; *Source: Softing ITNetworks*

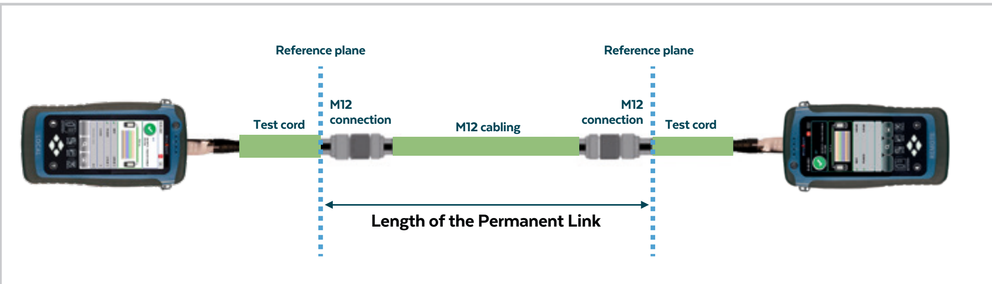
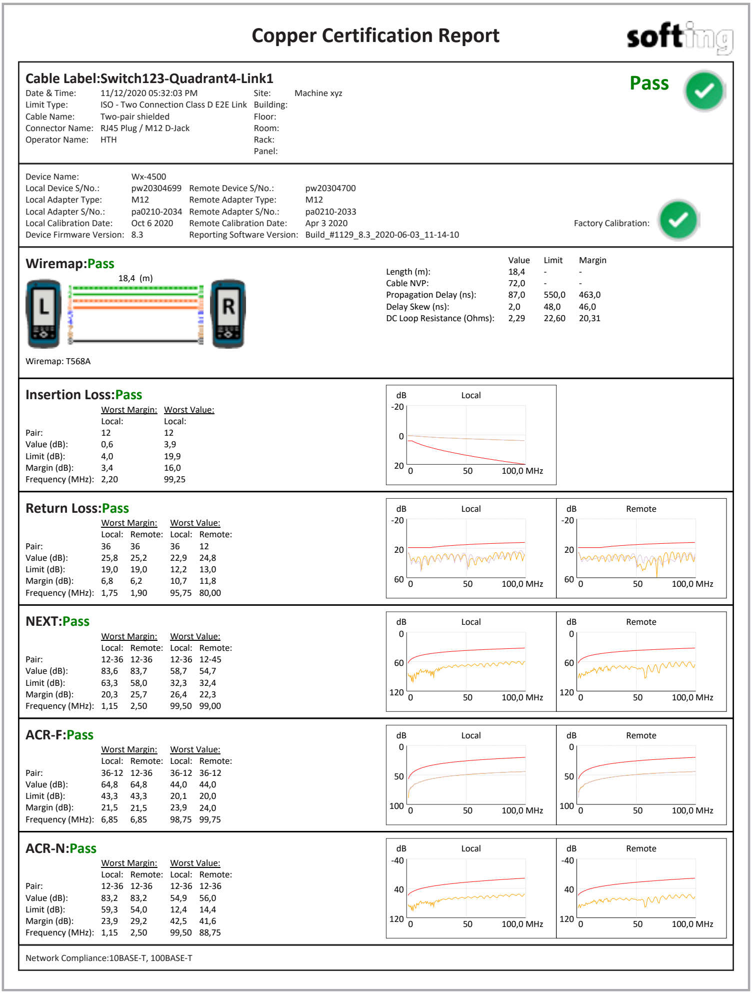


Figure 38: Arrangement for measuring M12 connectors; *Source: Softing IT Networks*



Copper Certification Report

Cable Label:Switch123-Quadrant4-Link1 — **Pass**

Date & Time:	11/12/2020 05:32:03 PM	Site:	Machine xyz
Limit Type:	ISO - Two Connection Class D E2E Link	Building:	
Cable Name:	Two-pair shielded	Floor:	
Connector Name:	RJ45 Plug / M12 D-Jack	Room:	
Operator Name:	HTH	Rack:	
		Panel:	

Device Name:	Wx-4500		
Local Device S/No.:	pw20304699	Remote Device S/No.:	pw20304700
Local Adapter Type:	M12	Remote Adapter Type:	M12
Local Adapter S/No.:	pa0210-2034	Remote Adapter S/No.:	pa0210-2033
Local Calibration Date:	Oct 6 2020	Remote Calibration Date:	Apr 3 2020
Device Firmware Version:	8.3	Reporting Software Version:	Build_#1129_8.3_2020-06-03_11-14-10

Factory Calibration: ✓

Wiremap:Pass

18,4 (m)

Wiremap: T568A

	Value	Limit	Margin
Length (m):	18,4	-	-
Cable NVP:	72,0	-	-
Propagation Delay (ns):	87,0	550,0	463,0
Delay Skew (ns):	2,0	48,0	46,0
DC Loop Resistance (Ohms):	2,29	22,60	20,31

Insertion Loss:Pass

	Worst Margin: Local:	Worst Value: Local:
Pair:	12	12
Value (dB):	0,6	3,9
Limit (dB):	4,0	19,9
Margin (dB):	3,4	16,0
Frequency (MHz):	2,20	99,25

Return Loss:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	36	36	36	12
Value (dB):	25,8	25,2	22,9	24,8
Limit (dB):	19,0	19,0	12,2	13,0
Margin (dB):	6,8	6,2	10,7	11,8
Frequency (MHz):	1,75	1,90	95,75	80,00

NEXT:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	12-36	12-36	12-36	12-45
Value (dB):	83,6	83,7	58,7	54,7
Limit (dB):	63,3	58,0	32,3	32,4
Margin (dB):	20,3	25,7	26,4	22,3
Frequency (MHz):	1,15	2,50	99,50	99,00

ACR-F:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	36-12	12-36	36-12	36-12
Value (dB):	64,8	64,8	44,0	44,0
Limit (dB):	43,3	43,3	20,1	20,0
Margin (dB):	21,5	21,5	23,9	24,0
Frequency (MHz):	6,85	6,85	98,75	99,75

ACR-N:Pass

	Worst Margin: Local:	Remote:	Worst Value: Local:	Remote:
Pair:	12-36	12-36	12-36	12-36
Value (dB):	83,2	83,2	54,9	56,0
Limit (dB):	59,3	54,0	12,4	14,4
Margin (dB):	23,9	29,2	42,5	41,6
Frequency (MHz):	1,15	2,50	99,50	88,75

Network Compliance:10BASE-T, 100BASE-T

Figure 39: Measurement report of an E2E cabling measurement; *Source: Softing IT Networks*

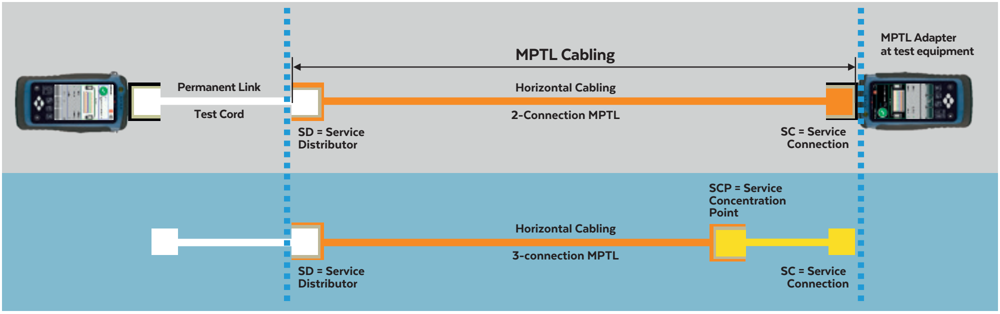


Figure 40: **M**odular **P**lug **T**erminated **L**ink (according to ANSI/TIA-568.2-D and ISO/IEC 11801-TR 9910); *Source: Softing IT Networks*

MEASUREMENT TECHNOLOGY FOR MPTL CABLING

A Modular Plug Terminated Link (MPTL) is a link described in **ANSI/TIA 568.2-D / ISO/IEC 11801-6 / EN 50173-6: Distributed Building Services**

For the connection of building services equipment (e. g. access points, cameras, sensors, etc.), the possibility has been created to connect them as a service connection (SC), directly to a service distributor (SD) or service concentration point (SCP). This means for the planner and the installer, it is permissible to either attach a modular connector (RJ45 plug) directly to the installation cable and connect it to the terminal device, or to use a flexible cable (patch cable) between the service concentration point (SCP) and the services device ***(see Figure 40)***. This means that these MPTLs end with an RJ45 connector, which means that it is not possible to measure a “Classic” permanent link here, since the link ends with an RJ45 connector. This is a similar problem to the measurement of patch cables and the E2E links. This means that you must work with a special measuring adapter to test the performance of the cabling link. This special adapter is the RJ45 MPTL-CATxx adapter, because with this adapter, it is then possible to test the performance of the entire MPTL cabling section. It is also important to use the correct adapter for the Class to measure, since these adapters, like the patch cable measuring adapters, are equipped with sockets that are matched to the measuring Class.

Conclusion: The requirements for cabling certifiers for patch cable, End-to-End and MPTL cabling measurements are certainly different from “normal” certification measurements on structured cabling systems. These can be mastered with today’s modern measurement technology if the manufacturers respond to these requirements and provide appropriate adaptations and settings for the measurement devices to meet these requirements. Softing meets these challenges with the WireXpert and provides a wide range of corresponding measuring adapters and measuring cables.

OUTLOOK

Finally, we would like to give a few examples here of the rapid increase in the amount of data to be transferred, especially via the servers in data centers and in the ToR (Top of Rack / Top of Row), EoR (End of Row) or MoR (Middle of Row) areas, i. e. in the rows of cabinets. As a result, the highest common transmission rates of 10Gb/s over copper cabling has been extended by higher requirements such as 25 & 40Gbit/s over Cat 8 / Class I & II copper cabling.

SMARTPHONES/BYOD

The growing number of smartphones, both in the business (BYOD = Bring Your Own Device) and private environment (our children), leads to more and more data traffic that our data centers must handle. Who today – in the age of flat rates and high-speed LTE transmission – still thinks about how many MBytes of data they are currently sending via their smartphone?

Nowadays, the good old SMS (Short Message Service) had its days. Instead, we now send high-resolution photos and HD videos via WhatsApp, YouTube, or similar services. This is certainly one of the points that is causing a higher data volume on the Internet and thus in the data centers.

TELEVISION/MULTIMEDIA

The four- or sixteen-times resolution of 4K-Ultra-HD / 8K-Super-High-Vision (SHV) with likewise higher color depth and higher frame rates compared to Full-HD naturally also means that the data volumes to be transferred in the acquisition and distribution of the contents become considerably more.

In production and post-production, where uncompressed data is mainly used, these enormous bandwidths already create major challenges, but at the latest when the content is transmitted to the consumer, the economic efficiency of the broadcast also plays a decisive role. With 4K-Ultra-HD and 8K-SHV, we are already talking about transmission rates of 10.2Gb/s and 24Gb/s, despite the introduction of new transmission standards such as H.265/HEVC.

AUTOMATION TECHNOLOGY

The importance of safe automation technology in the overall automation concept is increasing. Intelligent, safe control architectures give users the necessary freedom to individually implement the safety-relevant requirements for design, operating and service concepts as well as operator regulations.

This means that, especially in process automation with real-time control, data transmission technology is subject to ever increasing demands. The data volumes are growing and with them the bandwidths. In automation technology, too, the step towards 10Gb/s at the machines is already being initiated by the new M12 X-coded connectors. This will also lead to enormous data volumes.

WIRELESS NETWORKS

Wi-Fi (Wireless LAN) is already a standard in office and industrial environments. The trend towards higher bandwidths can no longer be stopped due to the ever-increasing amount of data that needs to be transmitted wirelessly: Higher bandwidths in Wi-Fi networks are becoming unavoidable. For this purpose, the new standard IEEE 802.11ac with gross transmission rates of 6.93Gb/s has already been adopted.

The access points working according to this standard will be supplied with data via 10Gb/s interfaces for operation. But also the Wi-Fi technology is already preparing for the next step, the Wi-Fi standard 802.11ax in the 2.4 and 5GHz band is preparing for data rates of 20Gb/s, but with lower ranges due to the necessary better signal-to-noise ratio.

CLOUD APPLICATIONS

VPN routers (modems) have established themselves in many places as a secure solution for remote maintenance and remote control of buildings, machines, plants, and so on. However, users in particular face numerous challenges when configuring site-to-site VPNs or network-to-network VPNs. Now, solution providers are offering cloud-based remote maintenance portals, a secure entry into remote maintenance and remote control with significantly more flexible functionality. Here, too, this means a rapid increase in data volumes between users and clouds.

We must face up the fact that measurement technology is no longer a simple comparison of a measured variable with a reference, measurement technology today means service and solutions for comfort, quality and safety.

AUTHOR

Thomas Hüsch, Dipl.-Ing. (FH) Communications Engineering

Senior Technical Support & Training at Softing IT Networks GmbH

About the author:

Thomas Hüsch studied communications engineering at the Bochum University of Applied Sciences and has been working in the field of cabling measurement technology for more than 25 years.

He has held technical positions with international companies such as Wavetek, Microtest, Avaya Systimax, and The Siemon Company.

Thomas Hüsch has been working for Softing IT Networks GmbH (formerly Psiber Data GmbH) since 2007 and has been conducting basic and measurement technology training courses since 1995.

Thomas Hüsch is also involved in standardization work for structured building cabling and measurement technology and is actively involved in various national and international standardization committees, such as the DKE, CENELEC and IEC, in the development of standards.

GLOSSARY

General information

- **CSMA/CD**: Term for access control with Ethernet for bus systems: Carrier Sense Multiple Access / Collision Detection
- **ANSI/TIA**: American National Standards Institute (ANSI), Telecommunications Industry Association (TIA), standards for the contacting of eight-pin RJ45 plugs and sockets. These standards are used for computer networks (LAN) in Ethernet (10Base-T, 100Base-TX, 1GBase-T, 10Gbase-T and 25/40GBase-T), as well as for many digital telephone systems
- **Permanent Link /Channel Link**: Definition of cable components in the tertiary sector, fixed data cable / fixed data cable + patch cable at both ends
- **TCP/IP**: transport protocol/Internet protocol, layer 4 and layer 3 transmission protocol (according to OSI, Open Systems of Interconnection), epitome of data transmission technology

About the Institute of Electrical and Electronics Engineers (IEEE)

The Institute of Electrical and Electronics Engineers (IEEE) is a worldwide professional association of engineers, primarily in the fields of electrical engineering and information technology, with legal headquarters in New York City and operations center in Piscataway, New Jersey, and is committed to promoting technology and its use for the benefit of the public. Through its widely cited publications and recognized conferences, technology standards, and professional and educational activities, the IEEE enjoys a high professional reputation on a wide range of topics, including space systems, computing and telecommunications, biomedical engineering, electrical power, and consumer electronics.

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Source: IEEE and IEEE-SA

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HEADQUARTERS
Softing IT Networks GmbH
Richard-Reitzner-Allee 6
85540 Haar, Germany

+49 89 45 656 660
info.itnetworks@softing.com

Find your local distributor:
itnetworks.softing.com/contact

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