SPE | INDUSTRIAL PARTNER NETWORK

APPLICATION NOTE

SINGLE PAIR ETHERNET – TESTING

CABLING TEST BACKGROUND

Measurements with a certifier (aka known as CAT tester or cable tester) after installation of cabling and also after moves, adds and changes of cabling is a proven means to ensure that the cabling indeed meets the performance requirements for a specific application. Test reports from those measurements serve for installer or facility technician installing that cabling, auditors, users and owners of that cabling as a documentation of the quality of the installed cabling.

Furthermore, measurements with a certifier help to reduce downtime caused by cabling damages dramatically because typically those damages can be found much quicker with a certifier than with any other method. This is valid both for office environments as well as for industrial applications.

In industrial environments, more and more ethernet is used as the dominant protocol to connect all kinds of devices. Ethernet has the advantage of being a common protocol that makes interoperability of devices much easier. On the other hand, Ethernet typically has higher RF (radio frequency) requirements on cabling hardware than many of the legacy protocols, which again makes measurements using a certifier more and more important.

Typically, copper Ethernet cabling consists of 2 or 4 twisted pairs and optionally one or more shields in form of foils or braids.

Since Single Pair Ethernet (SPE) only requires one pair and optional shields, one could assume now that not too much can go wrong in terms of cabling performance since the cabling construction is so much more simple than “classical” 2 or 4 pair cabling.

The following article will shed some light on measurements on SPE cabling and will highlight why also in SPE cabling, cabling measurements are an important tool to ensure compliance to standards AND a functional network.

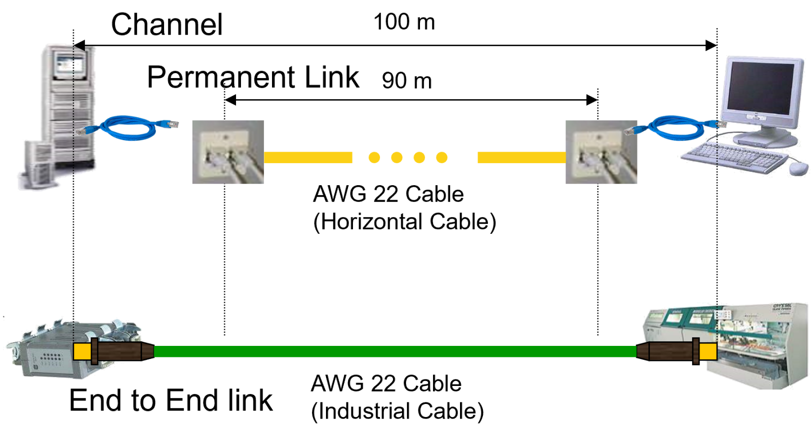
INTERACTION BETWEEN CABLIN AND MEASURMENT STANDARDS

Generic cabling standards like ISO/IEC 11801-1 and ANSI/TIA 568 or industrial cabling standards like ISO/IEC 11801-3, IEC 14763-4, and ANSI/TIA 1005 define all physical properties of the cabling. For measurements, the above standards refer to a separate set of standards that define how the above cabling is measured in laboratories and in the field.

On international level “classical” 2 and 4 pair measurements are well defined up to 2000 MHz in IEC 61935-1 for cabling and IEC 61935-2 for patch cords. With TIA 1183 and 1152, TIA defined a similar set of requirements for the above ANSI/TIA standards.

„CLASSICAL“ TWISTED PAIR CABLING MEASURMENTS

Cable certifiers are able to measure in different modes, depending on the necessities of a certain application



PERMANENT LINK

With “permanent link” the permanently installed link in a building is meant. Permanent links consist on a cable with sockets at both ends and an optional “consolidation point” which basically is an extension cable with a plug at one end and a socket at the other end. Both configurations does not include any connecting patch cables. To ensure that the first and last socket is installed properly, testers must include those in the measurement but also must mask out the rest of the measurement cables (see picture above). The “test plane” marks where the measurement starts and ends.

CHANNEL

In “Channel” configuration, certifiers measure all cabling including all connecting patch cords. It should be noted that the channel setup does not include the measurement of the first and last connector. Since measurements can only include a complete connection of plug and socket and the first and last socket is unknown, testers have to mask out those connections. See picture, test plane channel.

E2E LINK

End-to-end (E2E) cabling is a special cabling variant mostly used in industrial environments. E2E cabling has plugs on both ends of the cabling. E2E cabling may consist of just one cable with plugs at each ends but can also consist of up to 5 cabling segments.

Testers have to make sure that also the first and last plug of that configuration is measured.

Note that testers only supporting channel or permanent link configurations cannot be used for E2E cabling since they cannot assure that the 1st and last connector is measured properly according to standards.

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ADAPTION OF 4 PAIR TO 1 PAIR MEASURMENT – IS 1 PAIR CABLING “EASIER” TO MEASURE??

In some way one pair cabling indeed is easier to measure then two or four pair cabling since there is no interaction between pairs if only 1 link has to be measured.

On the other hand, SPE cabling opens up new challenges for cabling measurements since there are quite a few different SPE variants with widely different requirements and industrial cabling can additionally have much higher requirements on cabling in terms of immunity against electric magnetic interferences.

While the component and cabling standards for SPE are already ratified or close to being ratified, the measurement standards for SPE still are at the beginning of their development phase.

This is a typical approach since first the final cabling performance requirements have to be established before the definition off especially field measurement methods can be started.

The standards group IEC TC 46 WG 9 started a new project for SPE laboratory and field measurement techniques in autumn 2019. TIA started a similar project in TIA TR 47 back in summer 2019.

WHICH PARAMETERS NEED TO BE TESTED IN THE FIELD FOR SPE CABLING?

The answer to that question is at current (December 2020) not 100% clear yet. What needs to be measured when strongly depends on the environment, especially in industrial environments. Standards define the environment in MICE classes.

MICE stand for:

Mechanical specifications: requirements on robustness of a cabling system

Ingress specification: particle-, dust- and water-tightness requirements

Chemical specifications: requirements for the susceptibility against exposure chemicals like salt, oils or acids

Electromagnetic specifications: requirements for the susceptibility against external noise

MICE classes range from 1 to 3, where:

1. stands for low EMI requirements, eg. inside "normal" buildings
2. stands for "mild" EMI requirements, eg. outside buildings, light industry
3. stands for "tough" EMI requirements, e.g. heavy industry

Products can have different ratings for every part of the MICE classification, e.g. $M_2I_3C_3E_1$

From a measurement point of view, only 2 of the 4 parameters are interesting.

1) The "M" can have influences on the adaption to the measurement device since connectors for M_1 may be different to connectors for M_2 or M_3, so it is important to know if mechanical compatible measurement adaptors are available for a hand held tester. E.g. if a tester has no adaption to M12 systems for M_3, its can be difficult or impossible to measure a link with those components.

2) Since cabling has to be more (E_3) or less (E_1) protected against electromagnetic interferences (EMI), the "E" is from a measurement point of view the most critical parameter in terms of what has to be measured.

For E_1 environments, the question of "what has to be measured" is to the current status (December 2020) in standards committees pretty clear with the exception of Alien Crosstalk– see tables below.

For E_2 and E_3environments, there are today still a lot of open question on how to actually measure the susceptibility against EMI. TCL (see table below) is one potential candidate, however there are still open question on measurements on shielded cabling. There are also some laboratory measurements available like coupling attenuation (see table below), but these tests cannot be applied at reasonable effort to field conditions.

While there are still discussions in various standards groups around the topic of what has to be measured to satisfy requirements from MICE classes, the following aspects have to be considered as well:

1) Remote powering

If remote powering is required, the DC resistance of wires is important due to potential heating in cabling as well is the sheer fact if that cabling is capable to transmit the required power at all. 2 and 4 pair cabling has very clear requirements from a measurement point of view. Whereas it is completely sufficient to measure just DC loop resistance if the cabling is just used for "normal" PoE up to 15 W, DC resistance unbalance (DCRU) (see also table below) has to be measured if 4PPoE up to 60 or 90 W will be used. When such high power is send through relatively thin LAN cables, it is important that all wires have similar resistance in order to avoid heating up of single wires or pins.

With "Power over Data Line" (PoDL) SPE cabling will have its own remote powering definitions. In a nutshell, PoDL will provide several remote powering classes up to 50 W.

At current status (December 2020) it is unclear which DC resistance parameters need to be measured. The DC loop measurement is of cause possible, but it is not yet clear if that measurement is sufficient since the loop measurement cannot differentiate between the resistance of single wires. A DCRU (DC resistance unbalance) measurement would be theoretically possible on shielded cabling, but would simply not work on UTP cabling since DCRU is the measurement of a resistance of a single wire. On STP cabling, the shield could be used as a return path between the local and remote tester. On UTP cabling there is no return path.

2) **Alien Crosstalk (AXT)**

Alien Crosstalk defines the crosstalk between different links. For 2 or 4 pair cabling, Alien Crosstalk measurements are defined and can be measured with relatively high effort in the field. Users need to choose a certain number of links in a network as “disturbed” links to be tested against AXT. One by one, the “disturbed” links in that installation are then tested against all adjacent links to the disturbed link under test. Luckily for installers, AXT does not have to be measured in the field, if the manufacturer of the cabling system can prove coupling attenuation conformance in the lab. So in real world, this is no issue for shielded cabling but can become an issue for unshielded cabling. Manufacturers of unshielded system often just guarantee AXT performance.

This scenario will also apply to SPE cabling. However, there is also an additional scenario “cable sharing” that is not defined yet from a measurement point of view. One interesting cabling configuration for offices is that regular 4 pair cabling is used up to a consolidation point in a room. From the consolidation point, SPE cabling could be used to connect devices.

Each SPE link will be susceptible against AXT inside the 4 pair cable segment as well as to AXT between other SPE cables and other 4 pair cables.

The below table gives a short comparison of classical 2 or 4 pair cabling tests versus SPE cabling tests.

Issue	Test	2 or 4 pair cabling	SPE cabling	Comments
Connectivity	Wiremap	✓	✓	
	DC Loop Resistance	✓	✓	High DC loop resistance values dampen Ethernet signals. The value is also important for remote powering applications like PoE and PoDL. PoE or PoDL will not work if the link under test has too high values. This value is measured only from one side of the link.
	DC resistance unbalance (DCRU)	Optional		DCRU measures the resistance of individual wires, which is important for 4PPoE applications up to 90 W. If the DC resistance of individual wires differs too much, a link will heat up too much when 60 or 90 W are applied. This value is measured only from one side of the link.
Cable performance	Insertion Loss	✓	✓	High insertion loss reduces the signal strength of an Ethernet signal. This value is measured only from one side of the link.
Cable and connector performance	Return Loss	✓	✓	Bad connections or damages of the cable can cause signal reflections that distort Ethernet signals. The higher the return loss reading of a link, the less reflections are measured at link under test. This value is measured from both sides of the link.

Issue	Test	2 or 4 pair cabling	SPE cabling	Comments
Mainly plug and socket performance, but also cable performance	Near end crosstalk (NEXT)	✓		Crosstalk is mainly produced by connections, but also by low quality cables. Too much crosstalk can distort Ethernet signals This value is measured from both sides of the link
Link performance	Attenuation to Crosstalk Ratio at near end ACR-N	✓		ACR-N basically describes the remaining readable Ethernet signal level at one side of the link This value is measured from one both sides of the link
Link performance	Attenuation to Crosstalk Ratio at far end ACR-F	✓		ACR-F basically describes the remaining readable Ethernet signal level at the opposite side of the link This value is measured from one both sides of the link
Link performance	Power Sum NEXT, ACR-N and ACR-F	✓		Those values apply only to 4 pair cabling and are interesting for all Ethernet speeds from 1Gbit/s upwards. While NEXT, ACR-N and ACR-F only measure the influence between 2 pairs, the Power Sum values measure the influence of 3 pairs to one pair. Those values typically are not really measured but computed by test devices.
Disturbance between links	Alien Crosstalk (AXT)	✓	?	AXT describes the interferences between links that are in the same bundle or at the same panel. AXT measurements are only required if Coupling Attenuation values are below a certain criterion. AXT measurements are extremely time consuming and difficult to achieve in the field.

Issue	Test	2 or 4 pair cabling	SPE cabling	Comments
EMI	Transverse Conversion Loss TCL, ELTCTL	Optional	?	TCL is a similar measurement to Return loss, but measures the common mode signal that is reflected back to the transmitters TCL is an indicator for unshielded cables how resistive the cabling is against external noise. There are still open questions around TCL for screened cabling.
	Coupling Attenuation CA, Screening Attenuation	Lab only	Lab only	CA can effectively only be measured in laboratories. CA measures directly the immunity of cabling against external noise.

Table 1: comparison of classical 2 or 4 pair cabling tests versus SPE cabling tests

ACCURACIES FOR FIELD MEASURMENT DEVICES

IEC 61935-1 not only defines how to measure, but also which accuracies are required for laboratory as well as field measurements. The accuracy for measurements of „traditional“ 2 or 4 pair cabling is defined in levels analogue to the cabling classes in ISO.

Below table gives a summary of the current accuracy levels as per IEC 61935-1 ed. 5:

Level	Frequency range [MHz]	Corresponding ISO cabling Class
IIe	1-100	Up to D
III	1-250	Up to E
IIIe	1-500	Up to E_A
IV	1-600	Up to F
V	1-1000	Up to F_A
VI	1-2000	Up to I and II

Table 2: IEC 61935-1 ed.5 accuracy levels

The new single pair cabling classes as per the planned amendment for ISO/IEC 11801 will be defined by minimum length and supported frequency range:

Note: the values in below table are all from a draft document – they are not yet fixed and still may change!

Class	Frequency range [MHz]	Minimal length [m]
T1-A-100	0.1 – 20	100
T1-A-250	0.1 – 20	250
T1-A-400	0.1 – 20	400
T1-A-1000	0.1 – 20	1000
T1-B	0.1 – 600	
T1-C	1 - 1250	

Table 3: SPE cabling classes

Table 2 already shows that those accuracy levels will not fit to SPE cabling as per ISO/IEC 11801 because of 3 reasons:

A: the frequency range from 100 kHz to 1 MHz is missing. There are "only" 900 kHz missing so one could say that this is really not much. However, in radio frequencies, that is actually another decade that needs to be covered. At such frequencies, an interesting issue will be that the wavelength of a 100 kHz Signal in a copper cable is (depending on the NVP value of that cable) roughly 2.5 km. Studies will need to show what Return Loss accuracies can be achieved at all when measuring a link with say 100 meters length with signal with 2.5 km wavelength.

B: All current accuracy levels contain many internal parameters for field testers. Some of these parameters actually might not even be necessary for a device dedicated to SPE testing.

C: Above accuracy levels from IEC 61935-1 are only valid for the device, permanent link, channel and End-to-end link configurations, which are all point-to-point configurations. New

IEEE802.3 projects also work on point to multipoint configurations. Testing of such bus structures never was a scope of IEC 61935-1, so once that bus cabling also will hit ISO/IEC 11801 cabling standards, implications for field testers and accuracies need to be looked at as well.

The IEC workgroup TC46 WG9 therefore recently started a new project to develop an own testing specification based on IEC 61935-1 for SPE cabling. This new specification will become a new standard within the IEC 61935 series.

At current (Winter 2020) this work is still in its early stages. Since quite a number of open questions yet need to be discussed and clarified, it will take most likely 2+ years until a fully developed standard will become available.

CURRENT STATUS OF SPE FIELD TESTING

The companies HARTINTG and Softing cooperate on testing adaptors for the IEC 63171-6 series connectors. Early prototypes of the adaptors are shown on the following pictures. The first prototypes feature 4 single pair ports in order to also allow first test for Alien Crosstalk.

In this prototype setup, two measurement devices WireXpert 4500 are configured to work with the shown prototype adaptors. In order to only measure the SPE link, the devices must mask out both adaptor cables and just start the measurement right before the 4 port adaptors so that those are included in the measurement. The measurement cable itself comprise of Cat.8.2 components so those have minimal influence on the measurement.

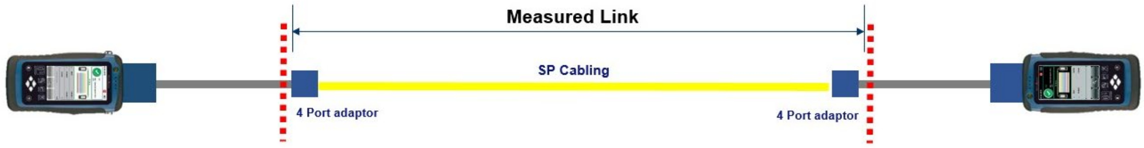

Figure 1: Measurement setup

Figure 2 WireXpert 4500 with SP prototype adaptors

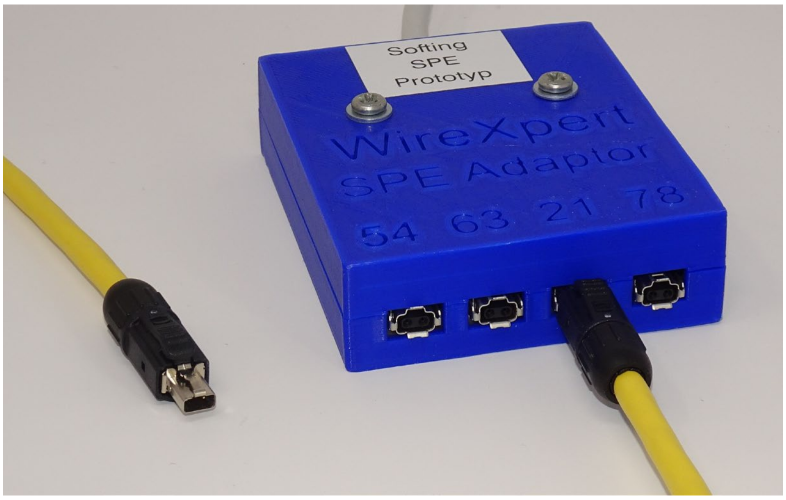

Figure 3: 4 port SP prototype adaptor for IEC 63171-6 connectivity

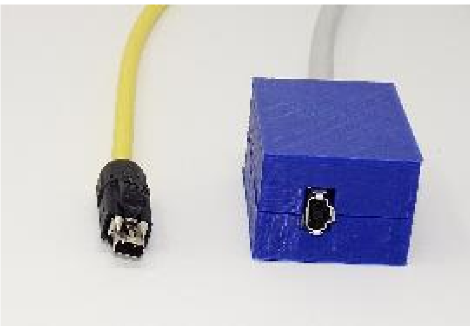

Figure 4: 1 port SP prototype adaptor for IEC 63171-6 connectivity

Softing, being the project editor of the new standard within IEC TC46 WG9, will use the knowledge gained by lab measurements as well as the above field test prototypes to help developing the new measurement standard for SPE cabling

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OUTLOOK

Single pair cabling has the potential to revolutionise Ethernet for the industry because of its simplicity and size of cabling components and the advantage to support Ethernet as a common transmission protocol at many different speeds while also providing remote power to devices.

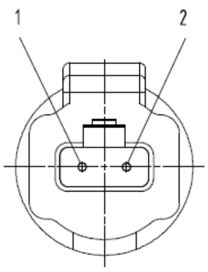
When many years ago the deployment of twisted pair for data communication became the de-facto standard for commercial buildings, the quality plans for those installations made tests with a certifier like the WireXpert Series almost to a "must have" to ensure that the installed cabling has the correct performance according to standards.

With the advancement of Ethernet in the industry, cable certification is becoming increasingly important in industrial applications as well not only for first installations, but also for moves, adds and changes of cabling.

With its vast variety of different cabling options, single pair cabling is indeed an interesting and new challenge for cable testing to properly address issues like testing accuracies and methods to ascertain EMI compliance in the field.

APPENDIX: WIRE COLOURS AND PIN ASSIGNMENT

Contact	PMA signal	PoDL	Wire colour
1	BI_DA+	PoDL+	Blue
2	BI_DA-	PoDL-	White



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