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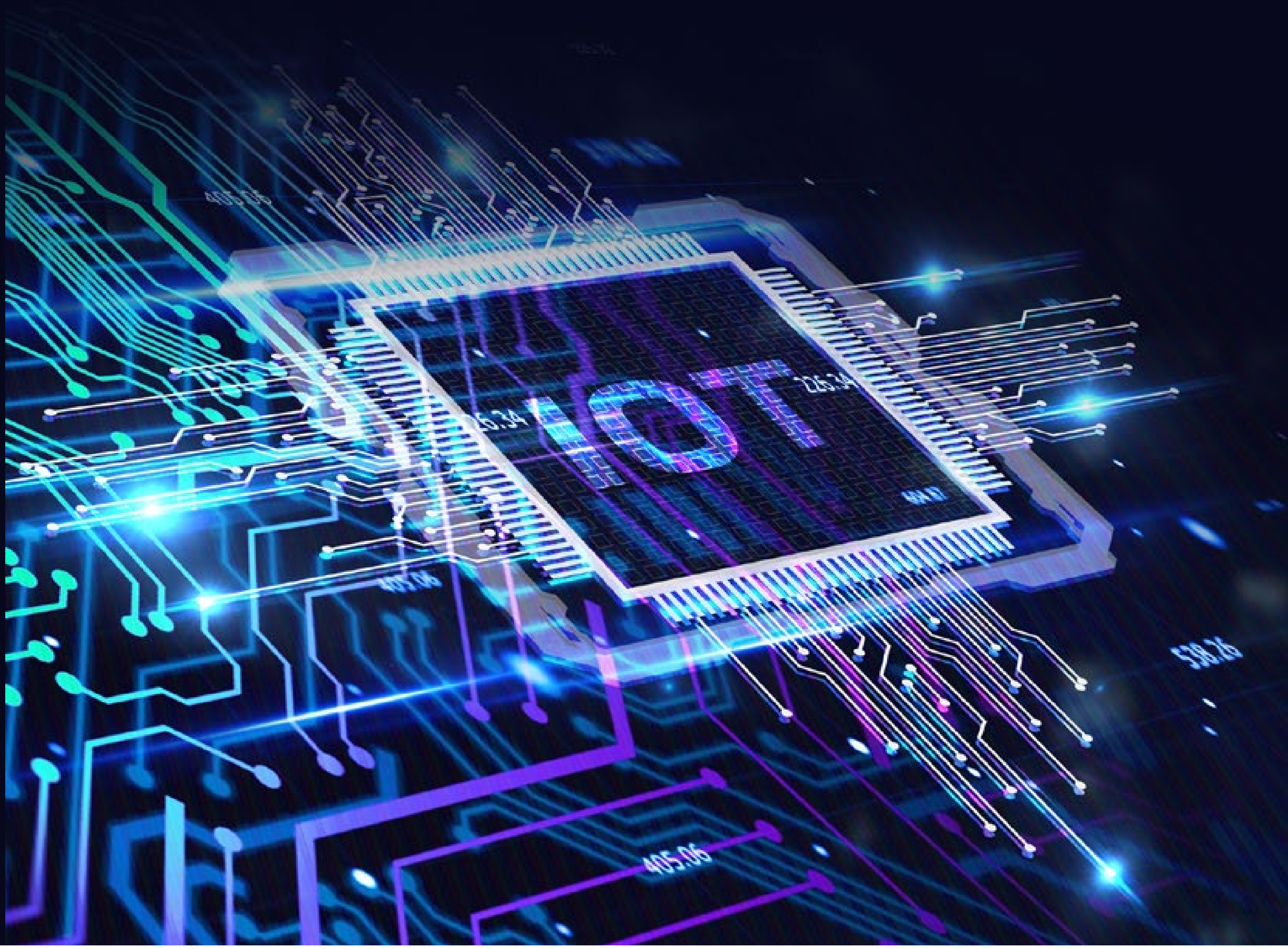
BACKWARD COMPATIBLE SPE CABLING: THE SUCCESSFUL PATH TO IoT INFRASTRUCTURES

Single Pair Ethernet (SPE) in IIoT and BIoT environments: scalable, investment-proof and high-performance



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SUMMARY

Abstract

The Internet of Things (IoT) in buildings (BIoT) and industrial environments (IIoT) continues to advance - with increasingly complex and sophisticated applications and devices. With this comes a huge demand for bandwidth and the need for integration capability with management software tools (BMS, Dashboards, MES, ERP) into an all-IP network. The technological pioneer for this is Single Pair Ethernet (SPE). It will certainly take time and further investments will be necessary until a complete migration has taken place. However, companies can already make their IT infrastructures „Fit for IoT“ today and gradually convert the existing IT environment to the new generation of devices.

In this white paper, the Multimedia Solutions BU (MMS) of Prysmian Group shows how companies can use SPE cables with legacy fieldbus protocols (Foundation Fieldbus, Profibus PA and PB, RS485, BacNet, Modbus, Canbus) (backwards compatibility). As part of the study, the cable expert compared the design, electrical characteristics of the primary performance criteria (capacitance, ohmic resistance, resistance unbalance) and the secondary performances (attenuation, impedance, return loss, balance and especially the frequency range of transmission) of legacy and SPE cables.

The research found that SPE cables are backwards compatible with key legacy protocols and are therefore suitable for use with legacy devices such as CAN, RS485, Foundation Fieldbus H1 and Profibus PA - but not Profibus DP. In view of the increasing quest for networking, SPE cables are the means of choice for future IIoT or BIoT applications. They prepare the existing infrastructure for the next generation of devices and replace the old buses gradually, without interruptions and short-term upgrades.

Finally, MMS investigated retrofitting legacy bus cables. However, this proved risky as the legacy bus protocols cannot deliver the bandwidth needed for SPE devices.

1. INTRODUCTION

Whether in building technology or in industry, the use of intelligent solutions is increasingly becoming the focus of modern automation processes. With smart infrastructures, environmental conditions can be monitored seamlessly and automatically adapted to user requirements at any time. They enable

- the worldwide remote access to information, machines and plants,
- monitoring of consumption and efficiency (e.g. energy, water),
- increased, multi-leveled access security and protection against hazards,
- customisable settings and profiling (e.g. light intensity, temperature balance),
- fast updates and a clear overview to facilitate maintenance and troubleshooting.

IoT applications require a new generation of sensors and actuators that communicate with each other in a network. They need to “see” more, “feel” more and analyse more. However, the traditional automation structure is coming up against limits that it must overcome.

With a view to the ISA95 automation pyramid, three different automation levels can be distinguished in a factory:

- The control level with ERP data collection, high level supervisory systems and visual monitoring of the plant status. The PCs communicate via traditional category cables network.
- The automation level with PLCs and other controllers that receive and process the logical and mathematical data and send the commands back to the shop floor. Communication between devices that use Ethernet-based protocols like Ethernet/IP or Profinet also takes place at this level.

- The field level with sensors, motors, electrovalves and other elements that detect or act on the processes. Here there is a multitude of different protocols, cables, connectors, data packets or analogue signals. They all run in parallel. If they are to speak to each other, a gateway active device must translate. This means more spare parts inventory, more specialists for different protocols and harder troubleshooting. In this level, we have legacy technologies that work for today’s applications but don’t have the bandwidth and integration capability for future IoT infrastructures. It is the only level of the automation pyramid that is not based on Ethernet.

In order to create an all-IP automation pyramid with a transparent structure that is visible and accessible to everyone, a uniform communication system is required beyond local infrastructures and across all levels. All components and devices must be fully networked with each other. The field level must communicate with the same Ethernet protocols and data formats as the upper levels. Only in this way can the conversion proceed efficiently and purposefully for the future.

The solution to bring Ethernet to the field level is called: SPE. SPE technology is the foundation for the IoT in factories and buildings of the future because it enables a continuous IP-based network. When all field devices speak the same Ethernet language, all areas, from the office to the sensor, can be connected. Networking is simplified and streamlined. Industrial application areas have so far preferred to use four-core copper cables, but these are less flexible, more expensive and do not provide a uniform connection of all field devices. SPE cabling can connect systems and be used in a variety of ways. It is not limited to any industry. In addition to the possibility of power supply, they cover data speed and distance, depending on the base. Moreover, automation with uniform protocols makes operation much more efficient in terms of maintenance, fault detection, spare parts or commissioning. Other advantages of SPE cabling: it is space-saving, inexpensive and easy to install, which is a great added value especially in small spaces. This makes it particularly attractive for the automotive sector and is used, for example, in automation technology, building automation, robotics or machine-to-machine communication.

The SPE application is standardised by the IEEE and uses a cable with a unique twisted pair to transmit data at 10, 100 or 1000 Mbps (802.3cg [1], 802.3bw [2], 802.3bp [3]) in channels to field applications **(see Table 1)**:

Table 1: SPE cable and applications

10 Mbps	100 Mbps	1 Gbps
IEEE 802.3 cg	IEEE 802.3 bw	IEEE 802.3 bp
1000 m	40 m	40 m
10 BASE-T1	100 BASE-T1	1000 BASE-T1

SPE enables the networking of all field devices via a simple construction cable with a much higher bandwidth for the new applications and sensors/actuators.

The key question is: Do users have to wait for the new generation of devices or can they start installing SPE cables now and use them with the legacy protocols installed? And what about the other way around? Can SPE applications run over legacy protocol cables?

1.1. Gradual Migration

The gradual changeover to SPE is the key to success. As is usually the case with innovations, an immediate changeover is difficult to implement in practice. A technology change including the replacement of all existing systems is complex and expensive and difficult to implement in parallel with ongoing operations. Especially the devices at field level need an active gateway device as a translator. Here, the changeover to SPE-compatible structures is much more laborious, cost-intensive and ultimately not yet fully implementable at every level. Therefore, a step-by-step conversion to SPE may be advisable: first the cabling, then the migration of the devices.

If the new SPE components are backwards compatible with the legacy applications, there is a good chance for a quick and trouble-free changeover to a successive SPE infrastructure in industry and buildings. The many physical layers installed facilitate the upgrade of the control network or automation by simply replacing the active elements.

Table 2: Legacy BUS cables with 2 wires

	RS485	Field. Found H1	Profibus DP	Profibus PA	CANBUS	BACNET
Design	1p SF/UTP	1p SF/UTP	1p SF/UTP	1p SF/UTP	1p SF/UTP	2 wires +GND
Standard	EI/TIA RS-485	IEC 61158-2	IEC 61158-2	IEC 61158-2	ISO 11898-2/11519-1	EIA/TIA RS-485
IEC 61158 Type	Type 3-B (Modbus)	Type 1	Type 3-A	Type 1	Type 3-B (Modbus)	
Conductor (stranded copper)	> 0.22mm²	> 0.8mm² (A), 0.32 (B), 0.13 (C)	> 0.34mm² (AWG22)	> 0.8mm²	0.25mm² to 0.75mm²	AWG22 (300m) to AWG16 (1200m)

2. METHODOLOGY

As part of the investigation into the backwards compatibility of SPE applications, MMS first evaluated the design aspects of the two groups of cables to be compared (SPE and Legacy). Since SPE cables only have one pair of wires, the cable expert also only used BUS cables with one pair as the transmission element, for example RS485 and Foundation Fieldbus. All other multipair legacy cables were excluded from the scope. The next step was to review the requirements of the standards for legacy BUS cables in order to create a basis for comparison with the SPE cable standards of the IEC. Finally, MMS compared the electrical properties such as capacitance, ohmic resistance and other primary electrical parameters to find out how the signals of the legacy protocols behave in SPE media.

2.1 Construction

The SPE cables consist of two insulated cores twisted in pairs and shielded (foil plus wire braid and polymer jacket) to protect against electromagnetic interference. Basically, these are cables with two cores and an overall shield.

The corresponding legacy protocol cables are listed in **table 2.**

The next step was to analyse the protocol requirements for the cable according to the standards to create a viable PHY (physical layer) for communication - free from signal distortion or noise above the limits.

2.2 Legacy Protocol Cables Requirements

There are two standards covering the minimum requirements for legacy bus cables: IEC 61158-2 [4] and IEC 61784-1 [5] for the various PHYs listed. In addition, for RS-485, the TIA recommended standard (RS) 485 [6] is a guideline. IEC 61784 regulates the organisation of the protocols according to the three layers of a simplified OSI model: PHY, DLL (Data Link) and AL (Application Layer), whereby the PHY is oriented to the types of IEC 61158-2 **(table 3).**

Table 3: IEC standardization of Bus cables in IEC 61784

CPF	Technology	IEC 61784-1, -2			CENELEC
		PHY IEC 61158-2	DLL	AL	
1	FF H1	Type 1	Type 1	Type 9	EN 50170-A1
3/1	PB DP	Type 3-A	Type 3	Type 3	EN 50254-3
3/2	PB PA	Type 1	Type 3	Type 3	EN 50170-A2
15	Modbus / RS485	Type 3-B			

Table 4: PHY types according to IEC 61158-2

Type	Type 1	Type 3-A	Type 3-B	Type 4	Type 18
Speed	31.25 Kbps	< 12 Mbps	< 1.5 Mbps	76.8 Kbps	< 10 Mbps
Impedance	100 Ω	150 Ω±15	115 Ω±15	100-120 Ω	110 **Ω**±15
Frequency	31.25 kHz	3-20 MHz	> 100 kHz	< 1 MHz	1-5 MHz
Attenuation	3dB/km	–		–	1.6 dB
Ohm. Resist	> 24 Ω/km	< 55 Ω/km	–	–	< 38 Ω/km
Conductor	> 0.8 mm²	> 0.34 mm²	> 0.22 mm²	> 0.22 mm²	2 AWG
Capacitance	–	< 30nF/km	< 60nF/km	–	< 60nF/km
Max link / speed	1900 m	12. km / 93 Kb 100 m / 12 Mb	1.2 km /93 Kb 70 m / 1.5 Mb	1200 m	100 m x 100 Mbps 1200 m x 156 kbps
Typical use	PB-PA FFH1	PB DP	Modbus RS485	P-NET RS485	TPMI PhL-B

DLL and AL have no influence on the cables. To understand what the requirements are, the PHY come into focus. Table 4 shows the different PHY types according to IEC 61158 **(table 4).**

Combining the bus protocols from Table 2 with the IEC media types (Table 4) results in Table 5, which gives guide values for comparison with the SPE cable values **(table 5).**

Table 5: Legacy buses and electrical requirements

	RS485	Field. Found H1 (Type A,B, C)	Profibus DP	Profibus PA	CANBUS	BACNET
Impedance Ω	115	100	150	100	120	115
Capacitance (max)	60 nF	80 nF	30 nF	80 nF	Typ 40 nF	100 nF
Ohmic Resistance [Ω/km]	98	< 24 (A), 56 (B), 132 (C)	< 55	< 24 (A), < 56 (B), < 132 (C)	< 70 (40 m) < 26 (1 km)	RS485 limits
Attenuation [db/km]	Not required	3 (A), 5 (B), 8 (C)	Not required	3 (A), 5 (B), 8 (C)	Not required	Not required
Frequency Range	31kHz-3MHz	31.25 – 39kHz	30 – 20MHz	31.25 – 39kHz	2 MHz	Acc RS485

3. SPE CABLE REQUIREMENTS

The requirements for SPE cables can be found in the following standards:
ISO/IEC 11801-1 Amd 1 [7]: There the generic SPE channels are defined, which are divided into classes T1-A, T1-B and T1-C for 10, 100 or 1000Mbps. T1-A is further divided into four channel lengths. According to the standard [7], complete SPE communication should run over the channels shown in the future. Some conductor sizes can already be determined from the equations of the insertion loss **(Table 6).**

ISO IEC 11801:9906 [8]: As a supplement, this standard contains a cable definition that relates the IEEE application to the cable standards of IEC 61156 [9][10] **(table 7).**

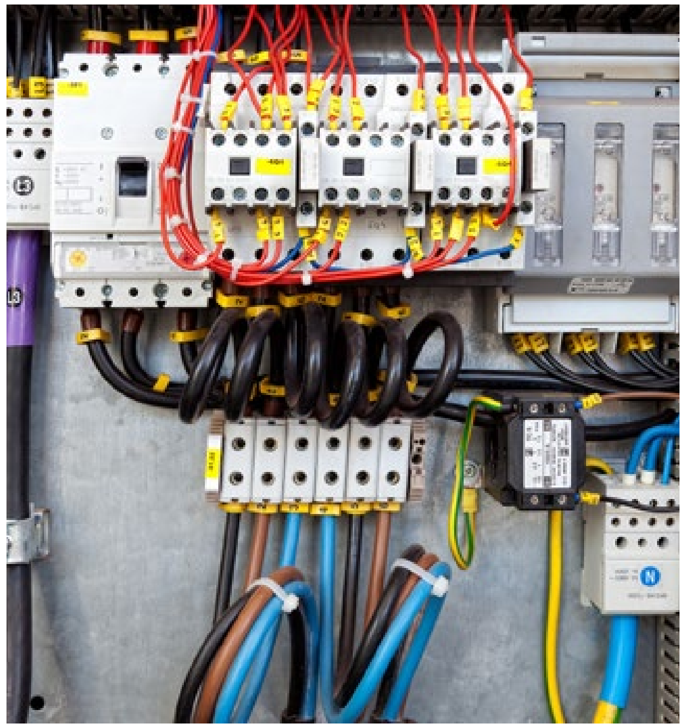
Table 6: ISO/IEC 11801-1 Amd 1 channels for SPE

Class	Subclass	Channel length (m)	IEEE Application	Wire Gauge (acc IL formula)
T1-A	**-1000 -400 -250 -100**	1000 400 250 100	20 MHz 802.3cg 10Base-T1	AWG18 AWG22 AWG23 AWG24
T1-B	**–**	100	600 MHz / 802.3bw 100BASE-T1	AWG23
T1-C	**–**	100	1250 MHz / 802.3bp 1000BASE-T1	AWG23

Table 7: ISO 11801-9906 channel definition

IEEE Application	Cable Std	Bandwith	Length
10 BASE-T1	IEC 61156-13, 14	20 MHz	T1L: 1000 m T1S: 15 m
100 BASE-T1	IEC 61156-11, 12	66 MHz	15 m
1000 BASE-T1	IEC 61156-11, 12	600 MHz	40 m

According to [9][10], there are some parameters that are not covered by IEC 61158-2 [4] and IEC 61784 [5], for example, balance measurements (TCL) and return loss. However, it is necessary that we compare the DC parameters (ohmic resistance, capacitance) and RF parameters (impedance, frequency range and attenuation if applicable) of SPE cables (AWG18, AWG22, AWG23 and AWG26 = patch cables) with the legacy bus systems from Table 5.



3.1 Low Frequency Measurements

To evaluate the impedance and insertion loss values below 0.1 MHz, four approved SPE cables were tested from 31.25 kHz to 100 kHz. This provided reference values for comparison with the bus cables **(table 8.)**

Table 8: Low Frequency results for SPE cables

Characteristic	SPE AWG18	SPE AWG22	SPE AWG23	SPE AWG26
Zo @ 31.25kHz (Ω)	121	138	140	149
Zo @ 100kHz (Ω)	109	116	120	130
IL @ 39kHz (dB/km)	3.8	5.7	4.5	6.7

4. VISUALIZATION: TRAFFIC LIGHT SYSTEM

To show the way in which SPE cables are compatible with legacy cables, MMS has chosen the following categories with the colours of the traffic light **(Figure 1).**

Figure 1: Traffic light system

SPE cable is fully compatible

SPE cable is compatible,
but some restrictions appear

SPE cable is NOT compatible

SPE cables assigned to the green category have full backwards compatibility with legacy systems. The yellow category means that the SPE cable is compatible with minor restrictions. These have only a minor effect on the application, for example in the form of reducing the maximum distance from 1200 to 1000 metres or lowering the maximum transmission rate from 10 to 9 Mbps. The typical applications work, if not always at full performance. Red means that there is no compatibility.

Tables 9 and 10 show the results of the survey.

Table 9: Backwards compatibility matrix- part 1

	RS485	Field. Found H1 (Type A, B, C)	Prfibus DB
Impedance Ω	115	100	150
Capacitance	< 60 nF	< 80 nF	< 30 nF
Ohmic Resistance (Ω/km)	< 98	< 24 (A), 56 (B), 132 (C)	< 55
Attenuation db/km	Not required	3 (Type A), 5 (Type B), 8 (Type C)	Not required
Frequency Range	31kHz-3MHz	31.25-39kHz	3-20MHz
Design	1p SF/UTP	1p SF/UTP	1p SF/UTP
Conductor	>0.22mm^2 (AWG24)	>0.8mm^2 (A), 0.32 (B), 0.13 (C)	> 0.34mm^2 (AWG24)
Back-Compat.	**YES**	**YES** but possibly some lenght restrictions	**NO**

For RS485 and BACNET, backwards compatibility is high for the three SPE cables AWG18, AWG 20 and AWG 22, except for the AWG26, which is a patch cable anyway, so not part of the main link. BACNET normally requires three conductors. Considering the SPE cable braid as the earth conductor, compatibility can also be established here. With Fieldfound H1 (FF) and Profibus PA (PB PA), the insertion loss is 0.8 dB above the limit. This can lead to connections shorter than 1900 m (about 1500 m). The impedance mismatch for AWG23 and AWG26 is 8% above the limit. Given the low frequency of these CPF (31.25kbps) with an electrical wavelength of 9600 metres, the reflections are not expected to be critical and interrupt or seriously affect communications. FF and PB PA are therefore in the yellow category. With Profibus DP, the impedance and capacitance deviations are too high, so that a classification in category red was made.

Table 10: Backwards compatibility matrix part 2

	Prfibus PA	CANBUS	BACNET
Impedance Ω	100	120	115
Capacitance	< 80 nF	Typ 40 nF	< 100 nF
Ohmic Resistance (Ω/km)	< 24 (A), 56 (B), 132 (C)	< 70 (40m) 26 (1km)	
Attenuation db/km	3 (Type A), 5 (Type B), 8 (Type C)	Not required	Not required
Frequency Range	31.25-39kHz	2 MHz	
Design	1p SF/UTP	1p SF/UTP	2 wires + GND
Conductor	>0.8mm^2	>0.25mm^2 to 0.75mm^2	AWG22 (300m) to AWG16 (1200m)
Back-Compat.	**YES** but possibly some lenght restrictions	**YES** but possibly some lenght restrictions	**YES**

For CANBUS, the capacitance is 12.5% higher than the typical CAN values and the impedance of the SPE cable is slightly below the CAN lower limit. This makes it possible for the clock signal to have a small distortion in the rise time of the signal. This small difference should not be a hindrance and should not affect communication, but it may affect the maximum distance and/or the maximum transmission rate.

The following **tables 11 and 12** summarises the compatibility of the SPE cables

Table 11: Backward compatibility acc to SPE copper size- part 1

	RS485	FF H1	PB DP
SPE AWG 18	Compatible	IL	Zo, Cm mismatch
SPE AWG 22	Compatible	IL	Zo, Cm mismatch
SPE AWG 23	Compatible	IL, Zo mismatch	Zo, Cm mismatch
SPE AWG 26	Compatible	IL, Zo mismatch	Zo, Cm mismatch

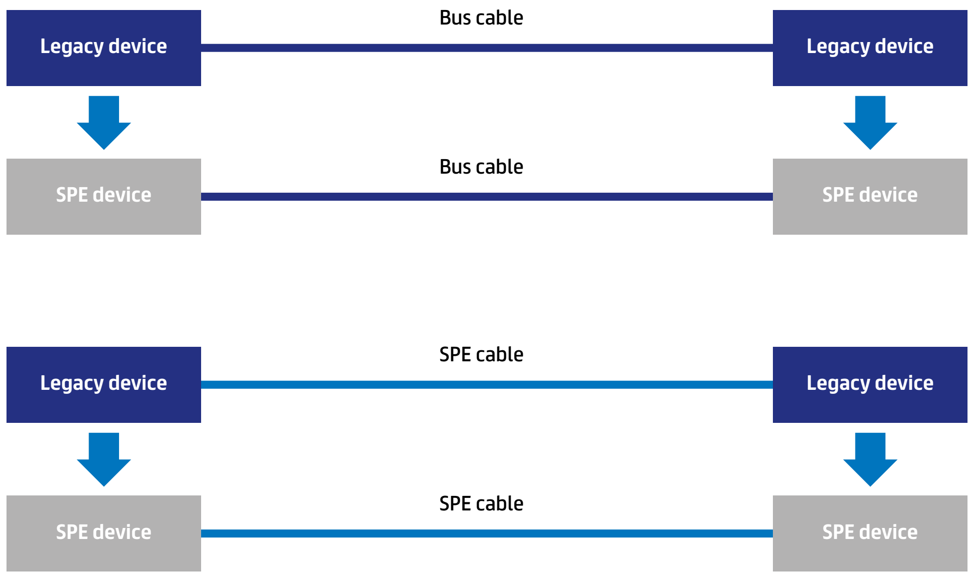
Table 12: Backward compatibility acc to SPE copper size- part 2

SPE Cable	PB PA	CANBUS	BACNET
SPE AWG 18	IL	Cm, Zo mismatch	Compatible
SPE AWG 22	IL	Cm, Zo mismatch	Compatible
SPE AWG 23	IL, Zo mismatch	Cm, Zo mismatch	Compatible
SPE AWG 26	IL, Zo mismatch	Cm 25% higher	Compatible

Fugure 2: Two approaches to deal with next gen devices

Retrofitting
Quick change of a Fieldbus device to a SPE device without changing the cable laid. SPE runs over the existing cable.

New Build
Using the same device with SPE cable using the possibility to change to an SPE device later.



5. RETROFIT OR NEW BUILD?

Retrofit or install new: That is the question? As shown in Figure 2, when retrofitting, the BUS cables remain in place and only the fieldbus systems are replaced by SPE systems. The SPE communication runs via the existing bus cables. Alternatively, it is possible to install SPE cables, continue to use the legacy devices and switch to SPE devices later **(Figure 2).**

The question is crucial because it determines the next steps and the planning of the infrastructure. If the retrofit works, the installed cables can remain in use and only the equipment is replaced. However, if retrofitting is not possible, it is advisable to start with SPE cabling right away. By preparing the infrastructure for the new generation of devices at an early stage, a costly and abrupt complete changeover of the infrastructure can be avoided.

The first step in evaluating whether a retrofit makes sense is to list the parameters that are limited by SPE standards and compare them with the parameters of the legacy bus cables. This results in the following overview **(Figure 3).**

Fugure 3: Controlled parameters in legacy and SPE cables

BUS	SPE
Ohmic resistance / copper mm2	Ohmic resistance
Capacitance	Capacitance
Inductance	Fitted Impedance (1MHz-20MHz) min 801 pts
Mean Impedance (<1MHz)	Return Loss
Insertion Loss at 31.25kHz	Insertion Loss (1-20MHz)
	Balance: TCL
	ELTCTL
	Prop. Delay
	Delay Skew
	Transfer Impedance
	Coupling Attenuation

SPE cables have a longer list of requirements that are not measured in legacy cables: Return loss, insertion loss at high frequencies, etc. The bus cables do not need to be tested for these properties in the manufacturing process. They may or may not be compatible with SPE. At this moment it is not clear. From this it can be deduced that the focus of bus cable manufacturers is not on making their legacy cables SPE-compatible.

Good values in return loss and TCL, for example, require good process control and tolerances that are not required for legacy bus manufacturing and do not affect the frequency range of the legacy bus (31kHz to 3MHz) as much. The same is true for shielding, which is rated differently at high frequencies, but does not place demanding requirements on legacy cables (if at all).

Then there is the impedance mismatch between legacy cables and SPE requirements. Some legacy bus cables have an impedance (Zo) of 120Ω in the range of 0.1 to 3MHz.

- RS485: 120Ω at f > 100kHz

- Field. Found / PB PA: 100Ω at 31.25kHz, so about 85-90 at 1MHz.

- CANBUS: 120Ω at 1MHz Profibus DP: 150Ω from 3-20MHz

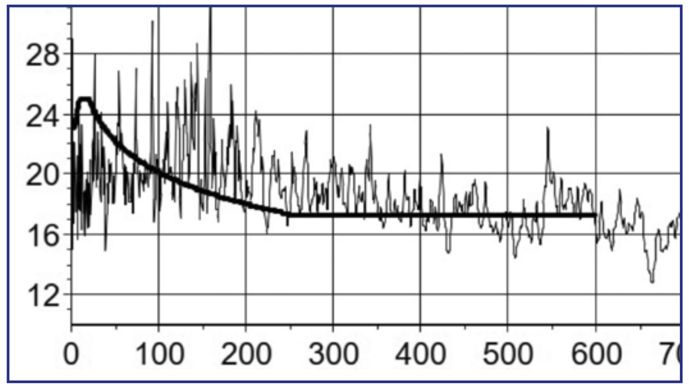
- Ethernet SPE cable: 100Ω ± 5 at 0.1-20MHz (IEC 61156-13) or 100MHz (IEC 61156-11).

Using the formula for return loss (RL), it can be calculated that the best value is 17 dB:

$$RL = 10 \cdot \log \frac{(Zo + 100)}{Zo \cdot 100} = 10 \cdot \log \frac{(120 + 100)}{120 \cdot 100} \cong 17$$

To confirm this calculation, the RL of a CANBUS cable was tested analogously to an SPE cable. The RL corresponded to the average level of 17 dB **(Figure 4).**

Fugure 4: Return Loss Fugure for bus cable as SPE



In addition, consider that SPE for 10BASE-T1 can achieve long link lengths such as 400 or 1000 m - by using intermediate connectors (up to 10 according to [7]), which increases impedance mismatches along the cable. A poor or defective legacy RL cable is not suitable for these critical link lengths.

5.1 Practical Results from Legacy Cables Samples

A group of RS485 and CANBUS cables were tested as SPE cables (with limits for T1A-400, T1-A-1000 and T1-B), resulting in the following error table, as expected **(Figure 5):**

Fugure 5: Legacy bus failure as SPE transmission

	T1-A-400	T1-B	T1-A-1000
RS485 AWG24	IL, RL, TCL, ELTCTL	IL, RL, TCL, ELTCTL	N/A
CANBUS AWG24	IL, RL	IL, RL, TCL	N/A
CANBUS AWG22+18	TCL, RL (22)	TCL, Delay, IL, RL (22)	IL, RL (18)

6. CONCLUSION

SPE provides a universal and more versatile standard for Ethernet connections via copper data cables in industry and building technology that is compatible with a large number of existing systems and protocols. In the long term, existing legacy systems at field level cannot withstand the technological change. However, migration takes time and investment. For many companies, the gradual conversion to future-proof solutions is a feasible and, above all, financially viable alternative. Especially backwards-compatible SPE cables, which are backwards-compatible with important legacy bus protocols and devices such as CAN, RS485, Foundation Fieldbus H1 and Profibus PA, enable successive retrofitting.

7. ACKNOWLEDGEMENT

We thank the members of the Single Pair Ethernet Alliance for the technical discussions and the preceding evaluation. We would also like to thank Ingeborg Dahl, Jürgen Müller and Lutz Hippe of the Multimedia Solutions BU of the Prysmian Group for their support with the SPE and bus cable measurements in the context of this white paper.

8. LITERATURE

[1] IEEE P802.3cg D2.1, IEEE Draft Standard for Ethernet – Amendment 5: Physical Layer Specifications and Management Parameters for 10 Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors

[2] ISO/IEC/IEEE 8802-3:2017/AMD1:2017, Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet – Amendment 1: Physical layer specifications and management parameters for 100 Mb/s operation over a single balanced twisted pair cable (100BASE-T1)

[3] ISO/IEC/IEEE 8802-3:2017/AMD4:2017, Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet – Amendment 4: Physical layer specifications and management parameters for 1 Gb/s operation over a single twisted-pair copper cable

[4] IEC 61158-2 Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition

[5] IEC 61784-1, Industrial communication networks – Profiles – Part 1: Fieldbus profiles

[6] TIA RS-485

[7] ISO/IEC 11801 Amd 1 – Amendment 1 – Information technology – Generic cabling for customer premises – Part 1: General requirements

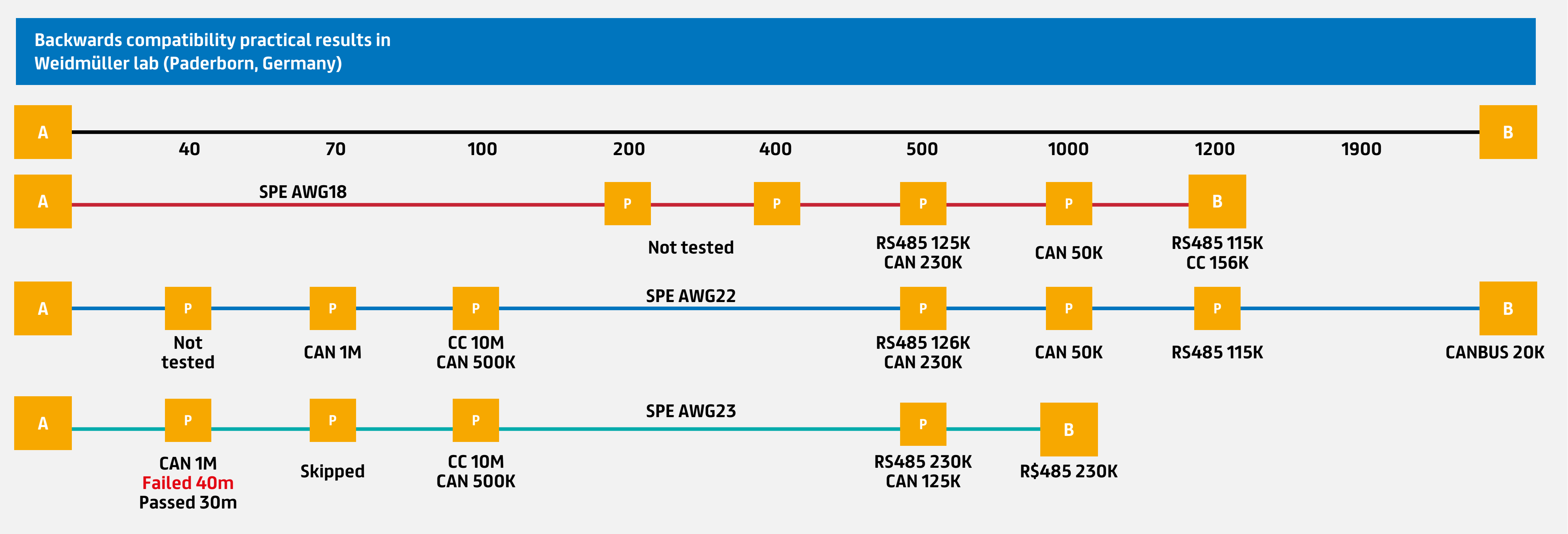
[8] ISO/IEC 11801:9906 – Information technology – Generic cabling for customer premises – Part 9906: Balanced 1-pair cabling channels up to 600 MHz for single pair Ethernet (SPE), Ed 1.0, Feb 2020

[9] IEC 61156-11, Multicore and symmetrical pair/quad cables for digital communications – Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification

[10] IEC 61156-13, Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – Horizontal floor wiring – Sectional specification

[11] TR.42.7-ANSI/TIA 568.5 Balanced Single Twisted-Pair Telecommunications Cabling and Components Standard, Draft 1.0a Feb. 2020

Those are the results of our SPE S1NGLE cables with real legacy bus devices, in Paderborn laboratories of Weidmüller, our partner in SPE System Alliance. The table has what we achieve and the maximum length for each speed and copper size, proving our theoretical predictions were right. The cable of tomorrow can help you also today.



Backwards compatibility practical results in Weidmüller lab (Paderborn, Germany)