White paper

Single Pair Ethernet in Building Automation

Using existing infrastructures for SPE

Learn more about

- → Single Pair Ethernet technology basics
- → Performance characteristics of existing cabling
- → Field-suitable measurement and test methods

Introduction

Especially in existing buildings, it is worth taking a closer look at the existing cabling infrastructure to minimize the ecological footprint of the building over its entire life cycle. But to what extent is it possible to reuse existing building automation cables for Single Pair Ethernet (SPE)?

Phoenix Contact set out to investigate this question by testing the various cable types used in building automation. When evaluating the cables, relevant electrical performance parameters were compared with the limit values of ISO/IEC 11801-3, IEEE 802.3cg, and IEEE 802.3da. In addition, the quality of signal transmission over different cable lengths was evaluated using parameters to assess the signal integrity.

> “It makes sense to use existing data lines with one or two wire pairs for SPE. This approach is sustainable and logical, especially when wireless-based communication is not possible or desired.”

Michael Radau,
Application Manager Building IoT Devices

Content

Determining the cable types

In Europe, the KNX protocol is widely used in building automation, especially in Germany. Type J-Y(ST)Y 2x2x0.8 cables are used to transmit bus signals in building system technology. These cables are also suitable for transmitting measurement data and are often used in HVAC applications with Modbus or BACnet protocols via RS485 interfaces.

Another cable that is frequently used is the cable type YV 2x0.8/1.4 switching wire, also known as bell wire. This is a twisted pair cable that is used for point-to-point connections where no high data rates or high power are to be transmitted.

To account for their widespread use, these two cable types were tested and evaluated in different lengths and configurations in order to determine the potential for their reuse in SPE connections.

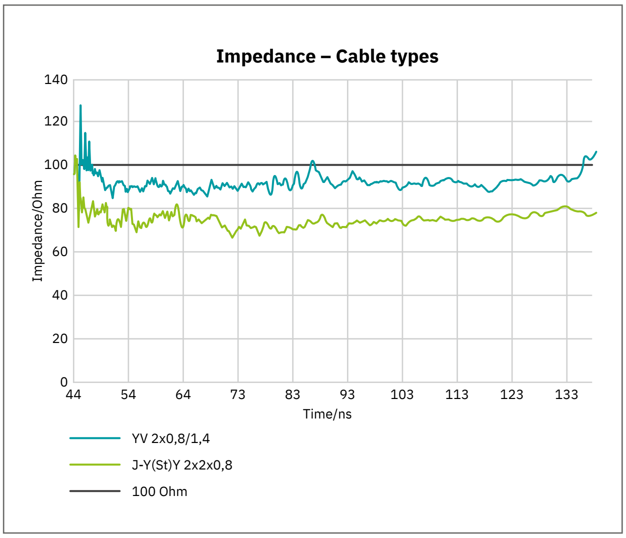
The usability of existing infrastructures for SPE forms the economic and ecological basis for the modernization of existing buildings.

Selecting suitable measurement parameters and methods

To simulate practical measurements, the cable measurements were carried out using the Fluke DSX 8000 field measuring device with an SPE measuring adapter. These field measuring devices are used to qualify Ethernet cabling and to test patch cables. Since the SPE measuring adapter used for testing the cables was a prototype, comparative measurements were carried out with the ZNBT, a vector network analyzer (VNA) from ROHDE&SCHWARZ, for verification purposes and compared with the measurement results from the field measuring device. For the measurements, the cables were terminated with the SPE connector from Phoenix Contact SPE T1 CIM SF to enable a quick and easy connection to the SPE measuring adapter.

Return loss (RL) is an important parameter for SPE transmission as it indicates the uniform impedance over the link length. The larger the RL, the better the attenuation of the reflections. RL measurements were carried out on 10 m, 40 m, 100 m, and 300 m long cables for each of the two cable types. The smallest deviations between the VNA and the field measuring device occurred on the long lines. For example, the RL measurement on the 300 m long KNX cable showed a deviation between 0.8 dB and 3.2 dB when comparing the values of the field measuring device and the VNA. For the shorter cable lengths, the deviations were larger, measuring up to 27 dB at some frequencies. Despite these measurement discrepancies, the measured values for RL were well above the required limits for all line lengths and cable types for a frequency range between 1 and 20 MHz.

The impedance of the lines was measured using a Time Domain Reflectometer (TDR). The average impedance measurements for the switching wire was 90 ohms and 75 ohms for the KNX bus line. SPE specifies an impedance of 100 ohms, so it can be expected that the lower impedance of the tested cables will have an influence in the range for SPE. The maximum ranges that can be achieved with the two cable types were investigated using signal-based measurement.



The impedances of the switching wire and KNX bus line deviate from the required 100 Ohm for SPE.

The attenuation of the signal can be mapped through the insertion loss (IL) of the cables. If the attenuation of the transmission path is too high, the decoder can no longer decode the signal at the end of the transmission path. If the impedance of the cable is variable or deviates from the impedance specified for Ethernet or SPE, the transmitted signals are reflected at the transitions or joints. With full duplex data transmissions, as is the case with 10BASE-T1L, the reflections on the transmission path must be small enough so that the received signal can be distinguished from the transmitted signal and its reflections. The return loss of the line is also crucial as it attenuates the returning reflections of the transmitted signal.

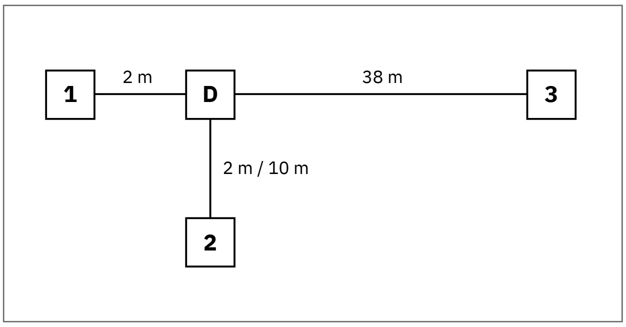
The transverse conversion loss (TCL) characterizes the resilience to electromagnetic interference. The TCL is easy to measure and allows an initial assessment of the susceptibility of data lines to electromagnetic interference (EMI). However, a TCL measurement does not replace specific EMC measurement procedures.

Investigating realistic cabling structures

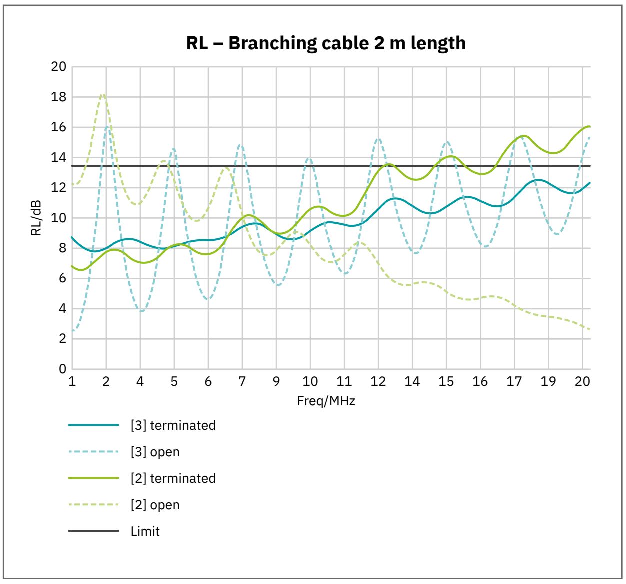
When reusing existing bus line infrastructures, unknown topologies may be present. In some cases, it may not be possible to dismantle the installed cables or the costs involved may be very high. In such cases, the existing installations often remain untouched. In other cases, the transmission path may involve a branch line, which could be long.

Consider a T-shaped line arrangement in which two-line sections form the trunk line, each 2 m and 30 m long. In one arrangement, a branch line with a length of 2 m branches off after the 2 m section. The 2 m branch line was replaced by a 10 m long branch line to form another arrangement.

In each case, measurements were taken from the start of the trunk line to the end of the branch line. The end of the trunk line was left open for one measurement and terminated for another measurement. Other measurements were carried out on both arrangements from the start to the end of the trunk with the branch line open for one measurement and terminated for another measurement.



T-shaped line arrangement of a trunk line with branch lines of different lengths.

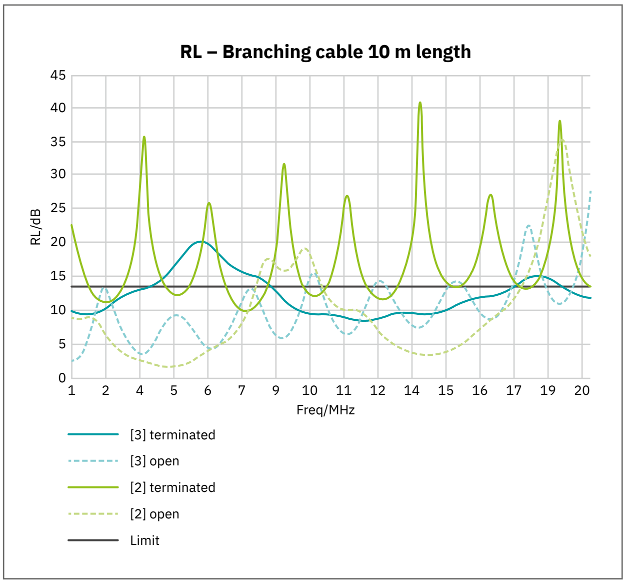


All RL values are largely below the required limit value curve.

The results for the insertion loss were well below the normative limit values for the short branch lines with a length of 2 m.

However, the results for the return loss show poor performance. With a terminated trunk line, there is a wave-shaped curve over the frequency, which rises steadily with increasing frequency from a minimum of 7.8 dB to a maximum of 12.5 dB. For the transmission channel, this means that in the worst case around 18% of the power of the transmitted signal is reflected. At the open end of the line, the waveform is very pronounced and increases steadily over the frequency from a minimum of 2.6 dB to a maximum of 15.4 dB. In the worst case, over 50% of the transmitted signal is reflected back into the transmission channel, making usability unlikely. The entire arrangement acts like a low-pass filter for reflections, in which low frequencies are minimally attenuated.

The arrangement with the 10 m branch line shows a similar wave-shaped curve for the RL.



The RL values for the 10 m long branch line with a terminated line end are close to the limit value curve.

The behavior is different for measurements that were taken from the start to the end of the trunk line with the end of the branch line terminated or left open. The measured values for the RL are still wave-shaped, but not as pronounced. For the terminated branch line, the reflections show a low-pass filter behavior. Over the frequency, the RL increases steadily from 6.6 dB to 16 dB, making this configuration usable for SPE transmission. An open branch line shows a high-pass filter behavior for the reflections. A steady drop in RL from 18 dB at maximum to 2.6 dB at minimum was measured over the frequency. The use of SPE in this cable arrangement is therefore not recommended.

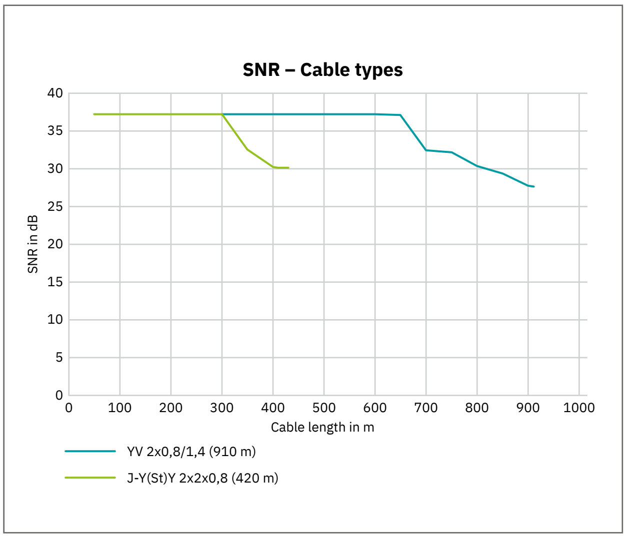
The same low-pass behavior occurs for reflections with comparable, and in some cases even higher attenuation values, as was the case with the 2 m branch line. The values increase steadily over the frequency from 2.5 dB at minimum to 27.4 dB at maximum. As before, using SPE with an open cable end is not recommended. If the end of the branch line is terminated, the reflections show a bandpass behavior. Over the frequency, the RL initially rises from around 9.5 dB to over 20 dB and then falls steadily to 8.4 dB. At 18 MHz, a further maximum of 15 dB is reached, which drops to 11.8 dB at 20 MHz. The RL allows a sufficient margin for using the channel for the transmission of SPE over the entire line.

Signal-based investigations

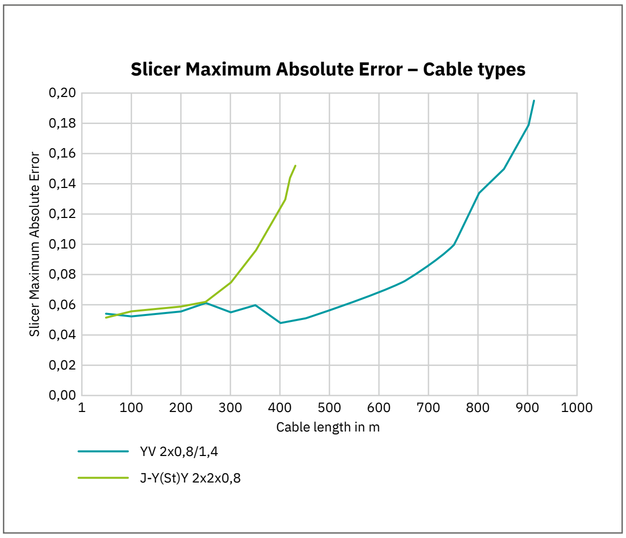
The previous measurements have shown that exceeding the normative limit values for SPE does not necessarily prevent data transmission. From a normative point of view, better components enable longer ranges and higher transmission rates. Conversely, poorer components shorten the range and lower the transmission rates.

To determine the maximum ranges that can be achieved for SPE with the KNX bus line and the switching wire, two evaluation boards were connected to the respective line. Both boards are equipped with the ADIN1100, which allows measuring the signal-to-noise ratio (SNR) and the slicer maximum absolute error. The two measured variables were used in an exclusion procedure to determine the maximum possible range for the respective line.

A range of 420 m was achieved with the KNX bus line, with the minimum SNR at 30.1 dB and the slicer maximum absolute error at 0.15. A maximum range of 910 m was achieved with the switching wire, and the values were just under 27.6 dB for the SNR and 0.19 for the slicer maximum absolute error.



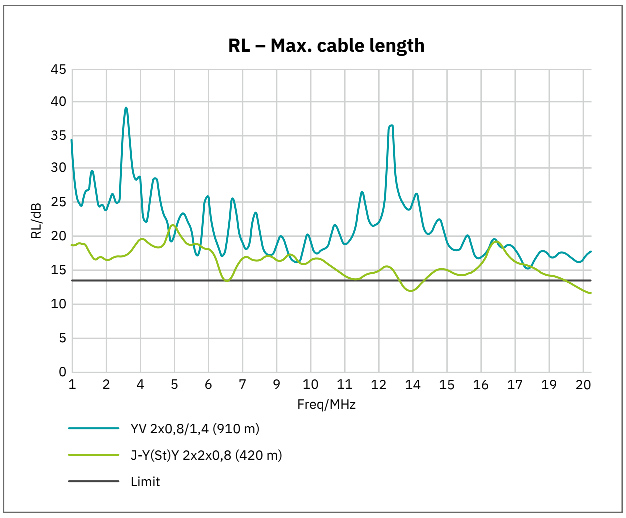
The maximum range of the KNX bus line is 420 m and 910 m for the switching wire.



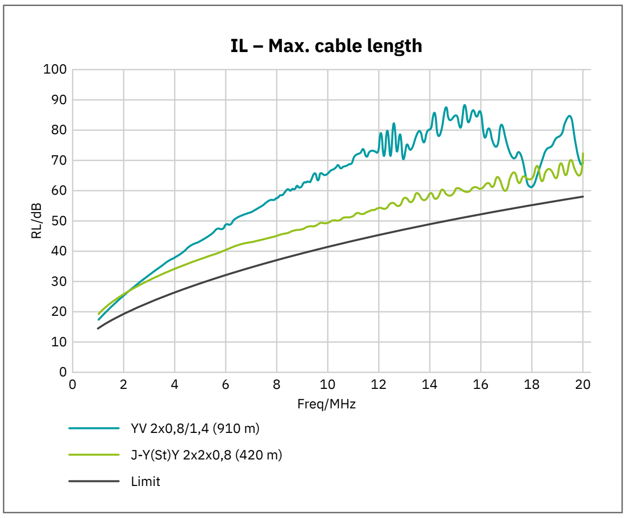
The slicer maximum absolute error is an indicator of signal quality.

According to the chip manufacturer, the SNR limit for the ADIN1100 is 20.5 dB. At this point a bit error occurs every 1000 s and the signal integrity becomes so poor that communication is no longer possible. Both boards were set to auto negotiation mode for communication. As communication was already no longer possible at SNR values of 30.1 dB and 27.7 dB, it is obvious that the auto negotiation setting also has an influence on the range.

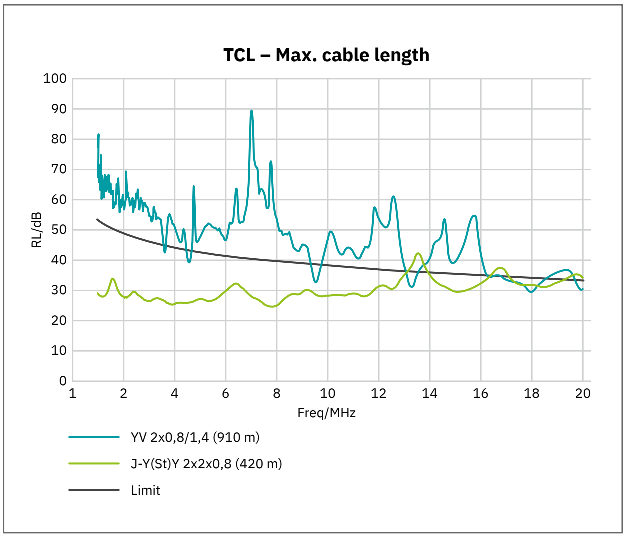
In addition, the values for RL, IL and TCL were measured for the maximum range or line length of the two-line types.



The RL values are largely above the required limit value curve.



IL values are all above the required limit value curve.



TCL values for the switching wire are largely above the required limit value curve, for the KNX bus line they are largely below.

For both the KNX bus line and the switching wire, the RL values are largely above the required limit value curve in the entire frequency range up to 20 MHz. The measured IL values are also above the required limit value curve for both lines. In the case of TCL, the results show a different picture – while the switching wire fulfills the required limit values, the KNX bus line falls below the limit value line.

Conclusion

The extent to which existing bus line infrastructures can be reused for the transmission of SPE depends on various factors. On the one hand, the existing topology is for a deciding factor when assessing usability. If transmission paths have branch lines, these should be removed if possible. If this is not possible or too costly, it is always necessary to terminate the open end of the line. Line impedance has a significant influence on the reflection of the transmitted signals and on the range. The closer the impedance of the line is to the 100 Ohm required for SPE, the less power is lost as reflections. Although the impedance of the KNX bus line is well below the setpoint at 75 ohms, a range of over 400 m could still be achieved.

"The possibility of reusing existing cabling infrastructure for SPE opens the door to digitalization for applications where cable upgrades are not possible."

Guadalupe Chalas,
Senior Product Marketing Data Specialist

Before an existing infrastructure is reused for SPE, qualification of the cables is always recommended. This is the only way to ensure that SPE transmission is possible. This can be done using field measuring devices such as the Fluke DSX 8000 with an SPE measuring adapter. For short-distance deployments, the focus should be on measuring the reflections. This makes it easier to assess the effects of any deviating topology or other interference points. For long distances, the attenuation of the signal is usually the limiting factor. If the limit values are adhered to, the channel can be used.

Furthermore, the investigations have shown that use is possible even if the normative limit values are exceeded. It is very likely that such cases occur more frequently in practice. It therefore makes sense to use SPE-capable devices to check the signal quality using SNR andthe slicer maximum absolute error, provided that the available SPE devices support this. This allows checking if the channels to be reused have an adequate transmission quality and signal integrity.

Contact

Contact us for more information

Our experts carry technological and product knowledge combined with extensive industry expertise. We will be happy to advise you on the possible applications and requirements of SPE in building automation.

Visit our website to find out more:
phoenixcontact.com/SPE

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