Expert contribution on

Wire diameter vs. current carrying capacity

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1. Wire basics

In all electrical installations we know one rule which everywhere is followed and till now was never questioned:

The higher the current, the larger the wire diameter or the cross section has to be. Some examples from power distribution networks in Switzerland:

Wire cross section	Maximum current carrying capacity
$1mm^2$	6A
$1.5mm^2$	16A
$2.5mm^2$	20A
$4mm^2$	25A
$6mm^2$	35A
$10mm^2$	40A
$16mm^2$	63A

2. What was first defined

IEEE defined two link segments in 802.3cg for 10Base-T1L:

- **A 1000m link:**

146.7.1.1.1 Insertion loss for PHYs in the 2.4 Vpp operation mode

For PHYs in the 2.4 Vpp operation mode, the insertion loss of each 10BASE-T1L link segment shall meet the values determined using Equation (146–10).

$$\text{Insertion loss}(f) \leq 10\left(1.23 \times \sqrt{f} + 0.01 \times f + \frac{0.2}{\sqrt{f}}\right) + 10 \times 0.02 \times \sqrt{f} \quad \text{(dB)} \qquad (146\text{–}10)$$

- **A 590m link:**

146.7.1.1.2 Insertion loss supported for PHYs in 1.0 Vpp operation mode

For PHYs in the 1.0 Vpp operation mode, the insertion loss of each 10BASE-T1L link segment shall meet the values determined using Equation (146–11).

$$\text{Insertion loss}(f) \leq 5.9\left(1.23 \times \sqrt{f} + 0.01 \times f + \frac{0.2}{\sqrt{f}}\right) + 10 \times 0.02 \times \sqrt{f} \quad \text{(dB)} \qquad (146\text{–}11)$$

It is important to understand, both link segments have the same wire diameter, therefore they have the same current carrying capacity.

3. How the confusion started

Cabling committees took the 590m link segment of AWG18 wires and made from it a 400m link segment of AWG23 wires.

So far that is not bad as both have the same attenuation, respectively the 400m link segment is always slightly below.

However, with the reduction of the wire diameter also the current carrying capacity was reduced.

Here as example ANSI/TIA-568.5, published on 25th February 2022, but both channels can be also found in ISO/IEC 11801-1 AMD1.
SP1-1000: AWG18
SP1-400: AWG23

6.3.7 Channel insertion loss

SP1-1000 single pair channel insertion loss limits are derived from equation (3).

$$InsertionLoss_{SP1-channel1} = 10 \cdot (InsertionLoss_{conn}) + (InsertionLoss_{SP1-1000_{cable_{1000m}}})\ dB \quad (3)$$

SP1-400 single pair channel insertion loss limits are derived from equation (4).

$$InsertionLoss_{SP1-channel400} = 5 \cdot (InsertionLoss_{conn}) + (InsertionLoss_{SP1-400_{cab\ \ 400m}})\ dB \quad (4)$$

Clause 6.6.6 defines cable insertion loss.

$InsertionLoss_{conn}$ is the insertion loss of connecting hardware.

$$InsertionLoss_{conn} = 0.02\sqrt{f} \quad (5)$$

Channel insertion loss shall meet or be less than the values determined using the equations shown in table 7 for all specified frequencies.

Table 7 - Channel insertion loss

	Frequency (MHz)	Insertion loss (dB)
SP1-1000	$0.1 \le f \le 20$	$10 \cdot (1.23\sqrt{f} + 0.01f + \frac{0.2}{\sqrt{f}}) + 10 \cdot 0.02\sqrt{f}$
SP1-400	$0.1 \le f \le 20$	$4 \cdot (1.82\sqrt{f} + 0.0091f + \frac{0.25}{\sqrt{f}}) + 5 \cdot 0.02\sqrt{f}$

3. How the confusion started

For completeness, here the channel list according ISO/IEC 11801-1 AMD1:

T1-A-1000: AWG18

All other channels: AWG23

6.6.3.2 **Insertion loss/attenuation**

The insertion loss requirements are applicable to all single pair cabling Classes.

The insertion loss (*IL*) of a single pair channel shall meet the requirements in Table 48. The insertion loss values for a single pair channel at key frequencies are given in Table 49 for information only.

Table 48 – Insertion loss for a single pair channel

Class	Frequency MHz	Maximum insertion loss [a] dB
T1-A-1000 [b]	$0,1 \le f \le 20$	$10 \cdot \left(1,23 \cdot \sqrt{f} + 0,01 \cdot f + \frac{0,2}{\sqrt{f}}\right) + 10 \cdot 0,02 \cdot \sqrt{f}$
T1-A-400 [c]	$0,1 \le f \le 20$	$4,05 \cdot \left(1,82 \cdot \sqrt{f} + 0,0091 \cdot f + \frac{0,25}{\sqrt{f}}\right) + 5 \cdot 0,02 \cdot \sqrt{f}$
T1-A-250 [c]	$0,1 \le f \le 20$	$2,55 \cdot \left(1,82 \cdot \sqrt{f} + 0,0091 \cdot f + \frac{0,25}{\sqrt{f}}\right) + 4 \cdot 0,02 \cdot \sqrt{f}$
T1-A-100 [c]	$0,1 \le f \le 20$	$1,05 \cdot \left(1,82 \cdot \sqrt{f} + 0,0091 \cdot f + \frac{0,25}{\sqrt{f}}\right) + 4 \cdot 0,02 \cdot \sqrt{f}$
T1-B [c]	$0,1 \le f \le 600$	$1,05 \cdot \left(1,8 \cdot \sqrt{f} + 0,005 \cdot f + \frac{0,25}{\sqrt{f}}\right) + 4 \cdot 0,02 \cdot \sqrt{f}$
T1-C [c]	$0,1 \le f \le 1\,250$	$1,05 \cdot \left(1,8 \cdot \sqrt{f} + 0,005 \cdot f + \frac{0,25}{\sqrt{f}}\right) + 4 \cdot 0,02 \cdot \sqrt{f}$

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 3,0 dB shall revert to a maximum requirement of 3,0 dB.

[b] Cord cable used in the channel is expected to have no de-rating based on construction.

[c] 10 m of 50% de-rated (based on construction) cord cable is assumed in the equation.

Related standardisation bodies took over the same specification, here as example SC46C, which is defining the cable for these channels. Also here, we have 2 different wire diameters:
A-1000: AWG18
A-400: AWG23

6.3.3.1 Attenuation at 20 °C operating temperature

The maximum attenuation, α, in the frequency range from 0,1 MHz to 20 MHz shall not exceed the values obtained from Equation (2) using the coefficients indicated in Table 3.

$$\alpha = a\sqrt{f} + bf + c/\sqrt{f} \quad (2)$$

where

α is the attenuation expressed in dB/100 m
a, b, c are constants indicated in Table 3
f is the frequency expressed in MHz

Table 3 – Attenuation equation constants

Cable type	Constants		
	a	b	c
A-1000	1,23	0,01	0,2
A-400	1,82	0,0091	0,25

4. Today's status

A look on all the homepages handling with SPE (TIA SPEC, SPE IPN and SPE SA) use the following keywords:

- **Thin cables**
- **Flexible cables**
- **Lower fire load**
- **Easier and faster installation**

If you ask anybody about SPE, they will tell you at least 2 of the points above, this are the market expectations.

The dilemma is obvious, we cannot deliver 1GBit/s or more over 1000m with 50W included. Somehow we have to bring the expectations into an area which is possible.

5. This slide to add

Title: Considering dependency of wire diameter and current carrying capacity

As wire diameter is a key parameter for current carrying capacity, smaller diameters will not allow the same amount of current per conductor. Therefore, the powering classes must be split into 2 groups:

- **Maximum current carrying capacity (today 2A) for AWG18 wires to provide the maximum power to the PD. This includes a future proof current increasement from todays 1.6A to 2.0A per conductor.**
- **Reduced current carrying capacity for AWG23 wires to provide reduced power of maximum 20W to the PD. All devices, sensors and actors which require more power must be wired with AWG18 wires only.**
- **Keyed connectors shall be used to avoid a wrong insertion of small wire diameters into a PSE capable to deliver the maximum power.**

Discussion