

# NVP's role in field-testing balanced twisted-pair cabling insertion loss

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Insertion loss is defined differently in ANSI/TIA specifications than it is in ISO/IEC specifications

By Igor G. Smirnov, RCDD, Signamax; and Bob Faber, RCDD/NTS Atras Network Communications

Despite the fact that telecommunications standards groups such as the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC; [www.iso.org/www.iec.ch](http://www.iso.org/www.iec.ch)) and the Telecommunications Industry Association (TIA; [www.tiaonline.org](http://www.tiaonline.org)) have “harmonized” virtually all transmission performance requirements, there is still one balanced twisted-pair transmission parameter that is defined differently and tested differently per the ISO/IEC and TIA requirements. This parameter is insertion loss (IL), also known as attenuation.

## Insertion-loss limits per ANSI/TIA-568-C.2 and ISO/IEC 11801

### ANSI/TIA-568-C.2

$$IL = 1.687\sqrt{f} + 0.0153f + \frac{0.18}{\sqrt{f}} + 0.00015f^{1.5}, 1 \leq f \leq 250 \text{ MHz}$$

where

f – frequency, MHz

### ISO/IEC 11801

$$IL = \frac{L}{100} \times (1.8\sqrt{f} + 0.01f + 0.2\sqrt{f}) + 0.02n\sqrt{f}, 1 \leq f \leq 250 \text{ MHz}$$

where

**L** - Total length of horizontal cable (fixed cable plus open office cable if present), m,  
**n** - Adjustment factor depending on the horizontal cabling configuration and taking into account the presence of an interconnection, cross-connection, and open-office cabling. For the purpose of writing this article, the following assumptions were made:

- n = 3
- The three connector permanent link model assumes that the horizontal cabling topology uses an interconnection
  - 1) in the horizontal cross-connect and the optional consolidation point
  - 2) was considered in addition to the telecommunications outlet/connector
  - 3) in the work area.

The insertion loss limits as defined in ANSI/TIA-568-C.2, shown by the formula on top, are constant because the TIA specifications are based on a 90-meter channel. The insertion loss limits as defined in ISO/IEC 11801, shown by the formula on the bottom, are variable because the ISO/IEC standard takes a more flexible approach.

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This article will address the Category 6 (ANSI/TIA) and corresponding Class E (ISO/IEC) cabling field-testing criteria, as it relates to installations of new cabling systems. Coincidentally, everything offered in this article may be applied to cabling systems of other categories/classes with appropriate adjustments to the corresponding formulae.

The fundamental difference between TIA and IEC specifications and IL-limit calculation methods lies in how the two standards define the maximum allowed length of the permanent link. These definitions are detailed in the figure below.

An additional condition is defined in ISO/IEC 11801: Insertion loss at all frequencies that correspond to calculated values of less than 4.0 dB shall revert to a maximum requirement of 4.0 dB.

**NVP formula**

$$NVP = \frac{V_{media}}{c},$$

where

$V_{media}$  – the speed of the signal in the media,  $\frac{m}{s}$  ;

$c$  – the speed of light in a vacuum,  $\frac{m}{s}$  ( $c = 299,792,458 \frac{m}{s}$  or, for short-cut calculations -  $3 \times 10^8 \frac{m}{s}$ )

The formula for nominal velocity of propagation (NVP) is shown here. NVP calculations are usually displayed as a decimal less than 1, such as 0.72, or as a percentage, such as 72%.

Although this note may appear to be insignificant, in fact this approach significantly alters the field-testing criteria and may lead to some misunderstanding among those who are unaware of its implications.

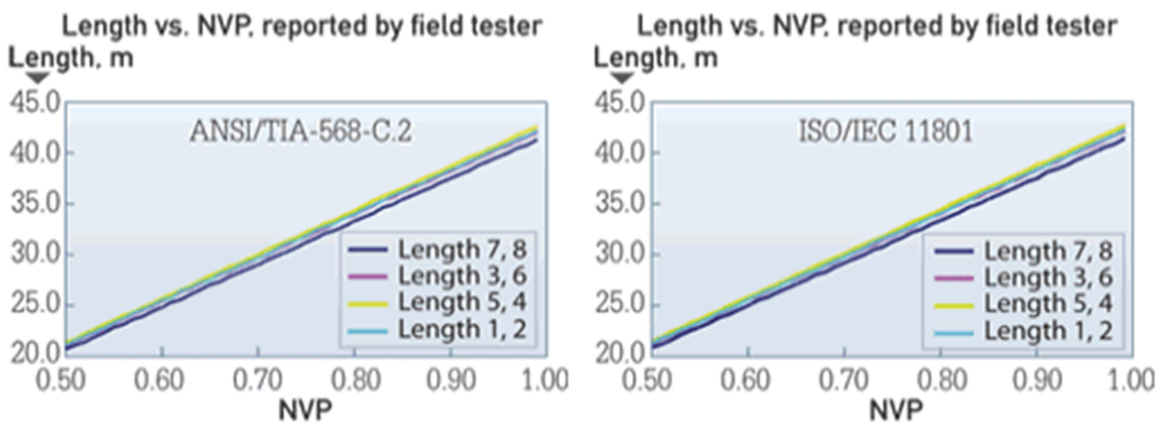
When field testing to the ANSI/TIA-568-C.2 specifications, the field tester should use the standard constant limit for each frequency test point (per ANSI/TIA-1152 requirements for testing procedures and field-tester accuracy) within the frequency range of interest, without any reference to the length of the permanent link under test. On the other hand, when testing to the ISO/IEC 11801 specifications, it is absolutely necessary for the field tester to acquire the actual length value of the permanent link under test in order to calculate the corresponding IL limit.

The only length of the object under test that is available to the field tester is the length it can measure. Because the tester can manipulate electrical transmission parameters only, the length can be measured based on the round-trip time (i.e., delay) of the signal launched by the tester into the transmission line. In order to calculate the distance (i.e., length of the link) the signal travels, the

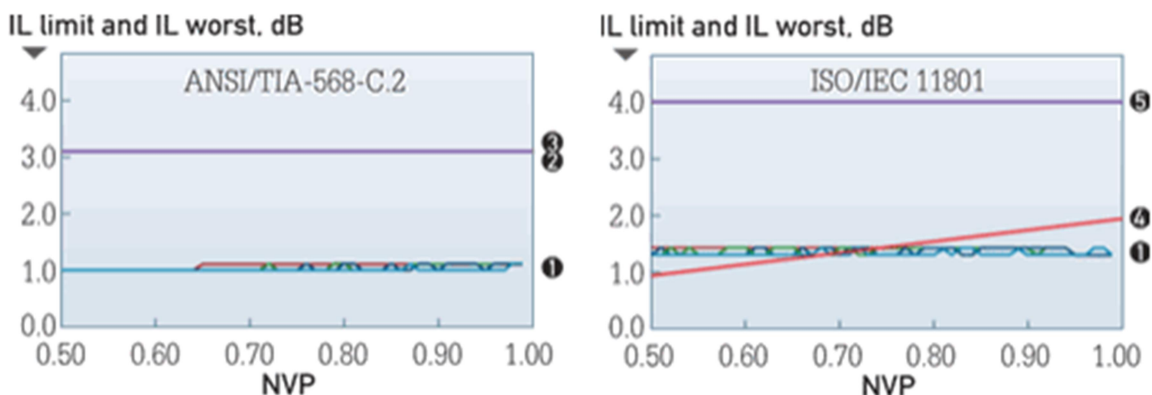
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tester should know the propagation time (also known as propagation delay or PD, measured in nanoseconds) and the speed of the signal propagation in the given transmission media. The measurement method used to characterize PD is known as the nominal velocity of propagation (NVP), which characterizes the speed of the signal in the balanced twisted-pair media relative to the speed of light in a vacuum.

NVP is a dimensionless parameter, usually expressed in two forms—decimal fraction (e.g., 0.72) or percentage (e.g., 72%). Because the speed of light in a vacuum is the highest speed that can be achieved by an object of any nature, NVP values are always below 1 or 100%, with values typical to common balanced twisted-pair cabling lying in the 0.6 to 0.8 (or 60% to 80%) range.



These graphs show length vs. NVP when a field tester tested per ANSI/TIA-568-C.2 (left) and ISO/IEC 11801 (right). The results show no difference between the length as measured in accordance with the two standards.



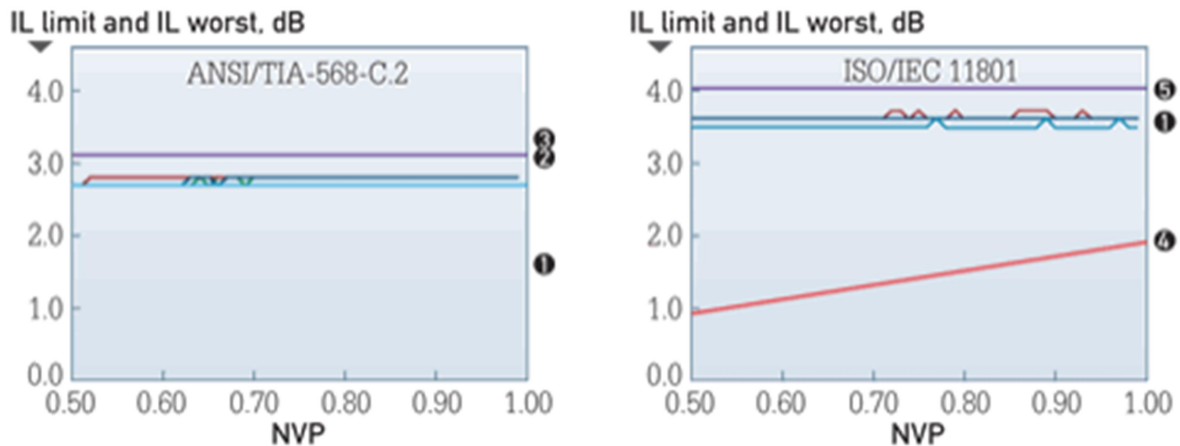
These graphs show insertion-loss limits and insertion-loss worst-case values that were reported by field testers on 30-meter cabling links. On the left is a set of results from a test conducted per ANSI/TIA-568-C.2 at 3.1 MHz and on the right is a set of results from a test conducted per ISO/IEC 11801 at 5.0 MHz. In the TIA test, the lines near the bottom of the graph are the worst-case results and the dark blue line near the top of the graph shows the insertion-loss limit as calculated using the 568-C.2 formula and as reported by the tester. The results coincide. In the ISO/IEC test, the lines

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near the bottom also are worst-case results. The red line is the insertion-loss limit as calculated by 11801 formula without considering the standard's "4-dB rule." The dark blue line near the top is the result reported by the tester and based on the standard's "4-dB rule."

Therefore, in order for the field tester to test permanent-link IL to the ISO/IEC 11801 specifications, it must have the accurate NVP setting. An inaccurate NVP setting will result in inaccurate IL measurement results.

In order to obtain experimental data, which may be used for illustrative purposes in this article, two lengths—30 meters (100 feet) and 90 meters (295 feet)—of Category 6 U/UTP cable were used and tested for IL and length using corresponding specifications of ANSI/TIA-568-C.2 and ISO/IEC 11801 as part of the field tester's firmware. During the experiments, we measured IL and length in relation to the changes in NVP. The field tester that we used in these experiments is capable of adjusting NVP in the range between 0.50 and 0.99 (50% and 99%).



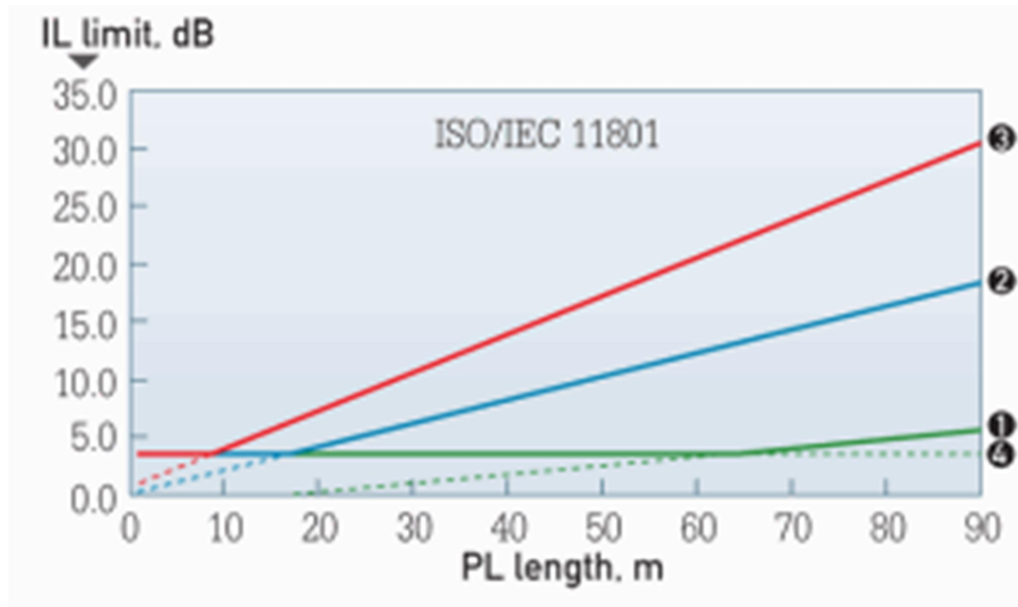
Similar to the previous graphs, these show the standard-calculated and tester-reported insertion-loss limits, along with worst-case values, for channels tested at 3.1 MHz per TIA specs (left). The graph on the right shows the calculated insertion-loss limit without considering the "4-dB rule" (red line), the tester-reported, "4-dB-rule-in-effect" limit (blue line), as well as worst-case values from tests conducted at 4.0 MHz according to ISO/IEC specs (right). These tests were conducted on 90-meter links.

Experimental data demonstrates there is no difference between length testing per the ANSI/TIA-568-C.2 and ISO/IEC 11801 specifications. In addition, from the test-result graphics, the degree of error can be estimated in case the NVP has been set incorrectly. For example, for one particular cable under test, NVP deviation from its actual value of 0.5 may lead to the error in length testing of up to 2 to 3 meters (6 to 10 feet).

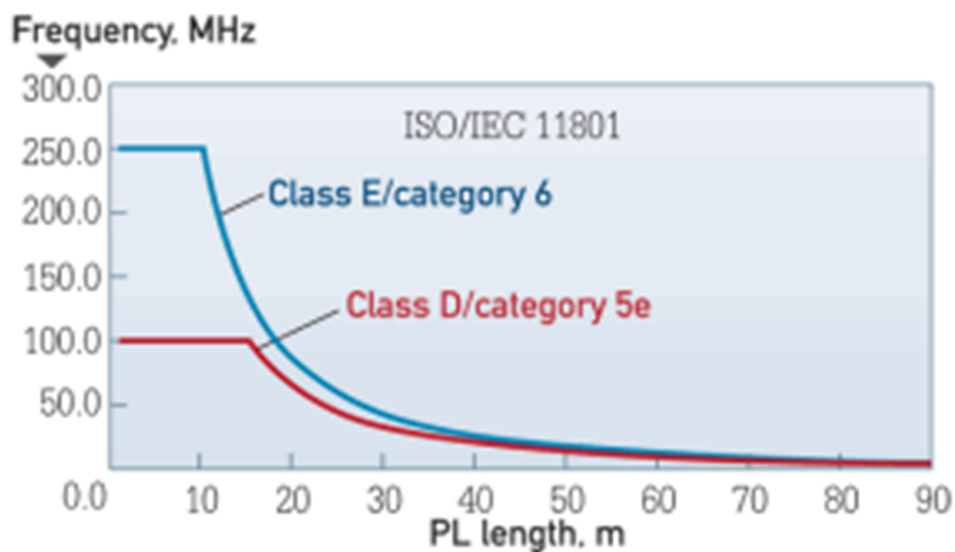
The graphics nearby offer an explanation of an actual example of the difference between testing per TIA and ISO requirements. When using the TIA approach, regardless of the length and NVP, the limit line is absolute for a given frequency. When using the ISO approach, the red line indicates what the limit would be if only the basic formula is used.

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In conclusion, we can make three statements about NVP and the field-testing of balanced twisted-pair cabling systems for insertion loss.



As this graph indicates, the “4-dB rule” comes into effect for links shorter than 10 meters. It also dominates pass/fail criteria at low frequencies.



This graph is meant to show A) the ISO/IEC “4-dB rule” is effective only on short links, and B) the insertion-loss characteristics in a Category 5e/Class D permanent link are analogous to those in a Category 6/Class E permanent link.

1) The correct NVP setting is necessary when testing permanent-link length per both TIA and ISO/IEC specifications.

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2) The correct NVP setting is necessary when testing permanent-link IL per ISO/IEC specifications. IL pass/fail criteria are directly related to field-tester length based on NVP accuracy.

3) The NVP value set in the field-tester memory does not influence IL testing per TIA specifications. Because calculations of the TIA IL limits do not involve NVP, accuracy of NVP setting cannot influence the resulting pass/fail criteria of IL testing.

**Igor G. Smirnov, RCDD is product manager with Signamax Inc. ([www.signamax.com](http://www.signamax.com)).**

**Bob Faber, RCDD/NTS is vice president of sales & marketing for Atras Network Communications ([www.atrasusa.com](http://www.atrasusa.com)).**