TITLE **Calibration of the noise injection level**

PROJECT SDSL

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STATUS for Decision

ABSTRACT The crosstalk noise levels are well-defined, but not under what test conditions this should hold. The level will change with the test loop impedance. An adequate description of this test condition, and how this can be verified by means of calibration, has recently been developed for ADSL. There is agreement within TM6 to follow the same approach for SDSL, but a literal text description is currently lacking. This contribution provides the text for inclusion into the SDSL standard.

1. Current Status of noise injection

To enable SDSL performance testing under noisy conditions, the crosstalk noise from the impairment generator is injected into the test loop as a current. The result of this approach is that the noise level (voltage) varies with the impedance of the cable. If the loop impedance is higher than 135Ω then the noise level is higher than was assumed when the SDSL performance requirements were set.

It has been found that this impedance mismatch troubles performance testing at lower frequencies. The SDSL standard makes the reader aware of this problem by means of a note (clause 12.3, table 12.1, note 8), and suggest a few short-term "solutions" to by-pass this error. The reader was noted that a long term solution is currently under study.

This long term solution has been solved recently within the ADSL project. The associated text was included into the ADSL document that was submitted for an official Approval by Correspondence. This solution was based on using a frequency dependent (complex) impedance, representing an "average" test loop impedance.
This approach was commonly accepted within ETSI-TM6, and proposed for adoption by SDSL as well. So far, the precise wording of this solution for SDSL was lacking.

This contribution provides this text, and is based on the description developed for ADSL. Only a few words have been rephrased to make the text suitable for SDSL.

2. Proposal

We propose to agree on the following:

- Replace the current SDSL text in clause 12.2.2 by the text below. The text in clause 12.2.2 is left unchanged, but renumbered into clause 12.2.3
- Delete note 8 in table 12.1 of the current SDSL document. This note has now become obsolete since the definition by means of a complex impedance has solved the whole problem. The levels at lower frequencies will no longer be emphasized by this new definition, which was caused by the old definition by means of a real impedance. It is left to the reader to calibrate this level by a complex impedance (direct procedure) or by a real impedance (needs calculations). Both methods are valid.

The attached text is a literal text proposal for SDSL.

Start of Literal text proposal

12.2.2 Noise injection network

12.2.2.1 Differential Mode injection

The noise injector for differential mode noise is a two-port network in nature, and may have additional ports connected to the impairment generator. The Norton equivalent circuit diagram is shown in figure 12.X. The current source I_x is controlled by the impairment generator. The parasitic shunt impedance Z_{inj} shall have a value of $|Z_{inj}|>4k\Omega$ in the frequency range from 100 Hz to 2 MHz.

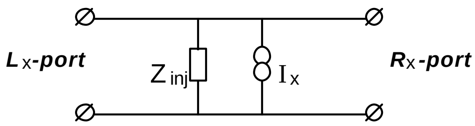

Figure 12.X Norton equivalent circuit diagram for the differential mode noise injection.

12.2.2.2 Common Mode injection

The specification of this injection network is for further study.

12.2.3 Signal and noise level definitions

The signal and noise levels are probed with a well-balanced differential voltage probe, and the differential impedance between the tips of the probe shall be higher than the shunt impedance of 100 kΩ in parallel with 10 pF. Figure 12.1 shows the probe position when measuring the Rx signal level at the LT or NT receiver. Measuring the Tx signal level requires the connection of the tips to node pair [A1, B1].

The various PSDs of signals and noises specified in the present document are defined at the Tx or Rx side of the set-up. The levels are defined when the set-up is terminated, as described above, with design impedance $\mathbf{R_V}$ or with SDSL transceivers under test.

Probing an rms-voltage U_{rms} [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals:

$$P = 10 \times \log_{10} (U_{rms}{}^2/R_V \times 1\,000) \text{ [dBm]}$$

Probing an rms-voltage U_{rms} [V] in this set-up, within a small frequency band of Δf (in Hertz), corresponds to an average spectral density level of P [dBm/Hz] within that filtered band that equals:

$$P = 10 \times \log_{10} (U_{rms}{}^2/R_V \times 1\,000/\Delta f) \text{ [dBm/Hz]}$$

The bandwidth Δf identifies the noise bandwidth of the filter, and not the -3 dB bandwidth.

12.2.4 Noise Levels Calibration

12.2.4.1 Differential Mode Noise Calibration

The differential mode noise injection is calibrated using the configuration shown in figure 12.Y. During calibration the R_x side of the noise injector is terminated by the design impedance $\mathbf{R_V}$ (= 135 Ω) and the L_X side of the noise injector is terminated by an impedance Z_{Lx}. The noise levels given in clause 12.5 specify the PSD dissipated in $\mathbf{R_V}$ on the R_X side when Z_{Lx} on the L_x side is equal to the calibration impedance Z_{cal}. The impedance Z_{cal} is defined in figure 12.Z.

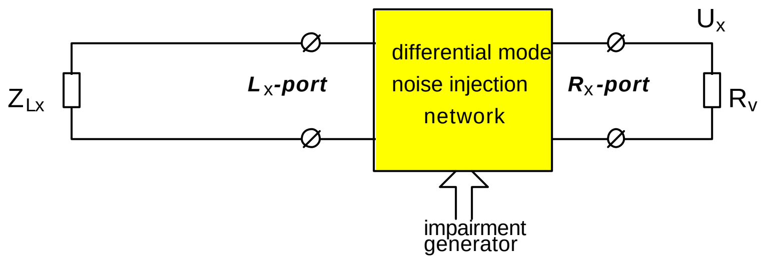

Figure 12.Y Configuration for noise level calibration

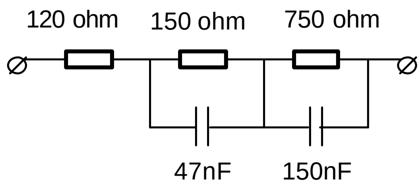

Figure 12.Z: Calibration impedance Z_{cal}

If the impedance Z_{Lx} on the L_x side of the noise injection circuit is equal to the calibration impedance Z_{cal} as given in figure 12.Z, then the PSD dissipated in the impedance R_v shall be equal to the noise PSD $P_{xn}(f)$ defined in clause 12.5.1.

Calibrating without using calibration impedance Z_{cal} (to simplify the test equipment) is feasible but complicates the overall calibration procedure. For an arbitrary value of the impedance Z_{Lx}, the PSD dissipated in Rv is equal to:

$$P_{cal}(f) = G(f, Z_{Lx}) P_{xn}(f).$$

The impedance dependent correction factor is specified as:

$$G(f, Z_{Lx}) = \left| \frac{\frac{1}{Z_{Lx}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}}{\frac{1}{Z_{cal}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}} \right|^2 ,$$

where Z_{cal} is the calibration impedance given in figure 12.Z, Z_{inj} is the Norton equivalent impedance of the noise injection circuit (see Figure 12.X), and R_v = 135 Ohm is the SDSL design impedance.

The noise generator gain settings determined during calibration shall be used during performance testing. During performance testing the noise injection circuit will be configured as shown in figure 12.1. Because the loop impedance and the impedance of the modem under test may differ from the impedance's Z_{Lx} and R_v used during calibration, the voltage over the Rx port of the modem may differ from the voltage U_x observed during calibration.

12.2.4.2 Common Mode Noise Calibration

This calibration method is for further study.

Replace the last two paragraphs of **clause 12.5.1** by the following text
(as was done for clarifying this for ADSL)

Each scenario (or noise model) results in a length-dependent and test loop-dependent PSD description of noise. Each noise model is subdivided into two parts: one to be injected at the LT-side, and another to be injected at the NT-side of the ADSL modem link under test. Therefore, seven individual impairment generators G1 to G7 can represent different values for each noise model they are used in. Specifically, G1 and G2 are dependent on which unit, LT or NT, is under test.

Generators G1-G4 represent cross talk noise. The spectral power $P_{xn}(f)$ for cross talk noise is characterized by the sum:

$$P_{xn}(f)= |A1|^2 \times \{ |H_1(f,L)|^2 \times P_{G1}(f) + |H_2(f,L)|^2 \times P_{G2}(f) + P_{G3}(f) \} + P_{G4}(f)$$

Each component of this sum is specified in the following clauses. Only the noise generators that are active during testing should be included during calibration. This combined impairment noise is applied to the receiver under test, at either the LT (for upstream) or NT (for downstream) ends of the test-loop.

Generators G5 and G6 represent ingress noise.

End of Literal text proposal