A SIMPLIFIED IMPULSE-NOISE MODEL FOR THE XDSL TEST ENVIRONMENT

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ABSTRACT

After presenting results of recent impulse-noise measurements in customer premises, a proposal for a simplified statistical model for impulse noise is presented. The new model is intended to replace the deterministic single impulse, widely known as Cook Pulse, especially in the upcoming standards for SDSL and also maybe VDSL. In addition to the statistical model also herein, sample impulses are defined. In contrast to the Cook Pulse, these impulses look like real impulses and are determined from an average power density spectrum and a group-delay average. Such single impulses should allow fast equipment checks but are not very suited for performance tests.

1 INTRODUCTION

Since no other models were available, yet, single impulses were originally used for modeling impulse noise. Especially in the HDSL standards document, a single impulse was defined which should represent some average power density spectrum. This so-called Cook Pulse unfortunately does not really represent the mean PSD which has been measured in a long-lasting campaign in the network of Deutsche Telekom. Additionally, because no phase properties have been taken into consideration, the time-domain shape of the impulse is far from what impulses on lines really look like. The impulse, in principle, also has an infinite energy which is made finite only by sampling and quantization. In the ANSI ADSL standardization, two real impulses have been included that once had been measured by Bellcore. These impulses may be more realistic than the Cook Pulse but, of course, two single impulses cannot represent statistical properties of real impulse noise.
In 1993/94 Deutsche Telekom had carried out an extensive impulse-noise measuring campaign [1-3], where especially impulses at central offices with mechanical switches had been recorded. It was already judged from an exemplary measurement that the statistics of impulse noise at customer premises in principal look alike the ones at central offices. The outcome of the 93/94 campaign was a statistical impulse-noise model that tried to incorporate all important properties of impulse noise, i.e., the mean PSD, the phase properties, the statistics of inter-arrival times, lengths, and amplitudes. Also a generator model based on specialized random-noise generators was presented [2-3].

For the upcoming of new standards for SDSL and also VDSL, an improved impulse-noise model is essential, since these standards will especially rely on error-control techniques. For defining error-correcting codes one has to know especially the statistics of inter-arrival times and lengths. Also for later performance tests, these are important properties for testing the error-correction procedures. Therefore, we decided to modify our original impulse-noise proposal such that it appears to be suited for standardization purposes. Furthermore, we did a new measurement in the basement of an appartment building, where another measurement had shown that the lines carry quite strong impulse noise. We again checked the statistics against our modeling approaches to show the validity once again. In the following Section 2, we present the new measurement results. The simplified model proposed in a recent ETSI contribution will be described in Section 3.

2 RESULTS OF A RECENT IMPULSE-NOISE MEASUREMENT AT CUSTOMER PREMISES' SIDE

Like in our earlier campaign, we again sampled 51,200 impulses and produced a histogram of the voltage values. This is given in Fig. 1 together with the modeling function

$$f_i(u) = \frac{1}{240u_0} \cdot e^{-|u/u_0|^{1/5}} \tag{1}$$

with a parameter u_0 = 3.1 nV. Thus, the original approach for the amplitude density is still suited for modeling the measured relative frequency distribution of the sampled voltages.

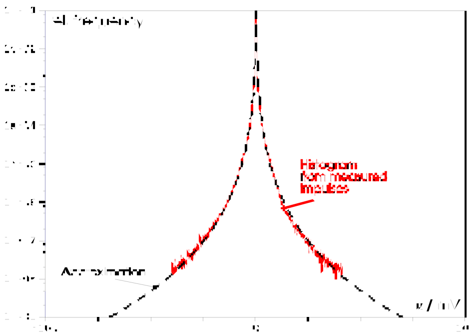

Figure 1. Approximation of the impulse-noise voltage frequency distribution.

The set of impulses was also used to derive a frequency distribution of impulse lengths. The result is shown in Fig. 2 in log and non-log representation. Our original modeling approach for the length statistics was a combination of two log-normal densities in the form

$$f_l(t) = B\frac{1}{\sqrt{2\pi}s_1 t}e^{-\frac{1}{2s_1^2}\ln^2(t/t_1)} + (1-B)\frac{1}{\sqrt{2\pi}s_2 t}e^{-\frac{1}{2s_2^2}\ln^2(t/t_2)} \tag{2}$$

The recent measurement at customer side obviously has a length distribution that can be approximated by only one log-normal density. The parameters are B=1, s_1=1.15, t_1=18.1 µs.

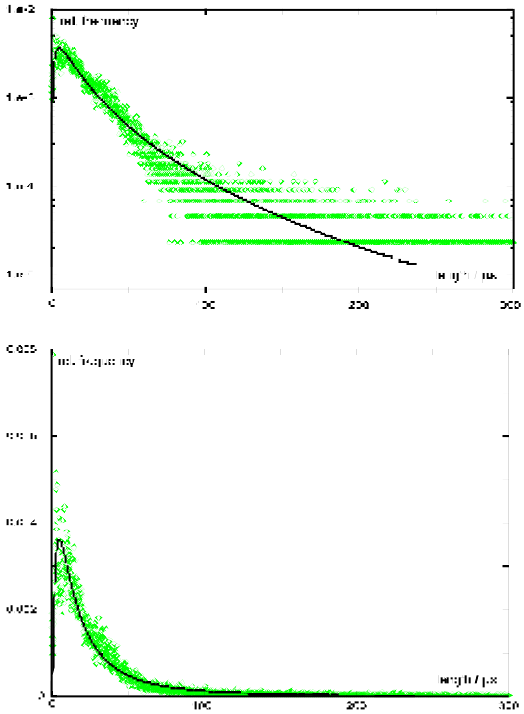

Figure 2. Frequency distribution of the length of impulses (logarithmic and linear).

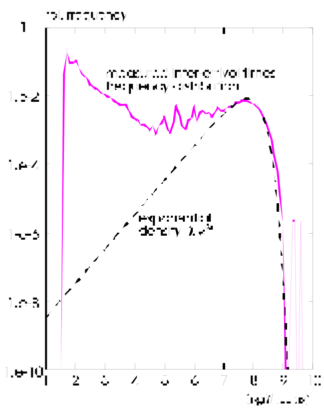

Figure 3. Relative frequency distribution of the inter-arrival times.

We also did separate measurements of inter-arrival times. The results are shown in Fig. 3. This time, the statistics followed the exponential density of a Poisson process $f(t) = \lambda e^{-\lambda t}$, $\lambda = 0.16$ Hz, quite well and we did not need the rather complex generalization applied in [1-3]. Anyway, for performance tests, we would consider the Poisson law to be more relevant. The deviations from the exponential density that we have recognized in the earlier measurements are mostly due to strong variations of the impulse rate during long measurement times.

From the sampled impulses, we also determined the mean power density spectrum (with reference to a 200 µs long period) which is shown in Fig. 4. Furthermore, also the phase differences between neighboring DFT samples at a distance of 5 kHz are shown and modeled in Fig. 5.

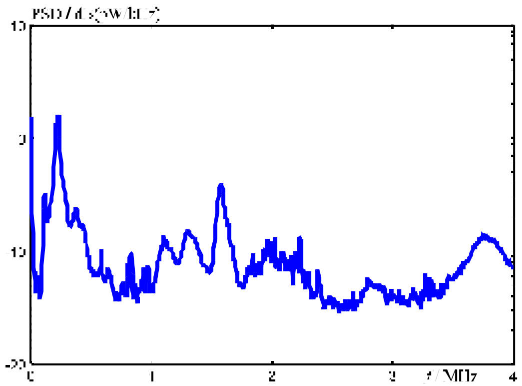

Figure 4. Power spectral density.

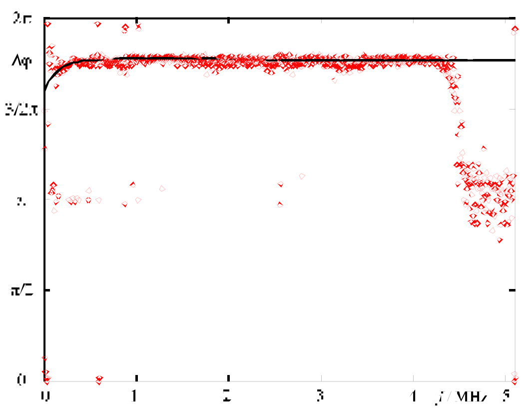

Figure 5. Phase differences between neighboring spectral lines.

The phase differences, which are effectively the group delay, roughly follow the approximation

$$\Delta\varphi(i\Delta f) = 5.0 + 0.55\cdot(1 - e^{-i/30}) - 4\cdot 10^{-5}\cdot i\,. \tag{3}$$

This formula has the same structure as in our earlier campaign. The only difference is that the falling slope (rightmost term) was different, i.e., the factor was different.

From the mean power spectral density and the typical phase function, we computed a representative impulse which we propose as an alternative impulse model for simplified equipment tests. This customer premises impulse is shown in Fig. 6, together with one for the central office in the case of mechanical switches, which was computed from our earlier data.

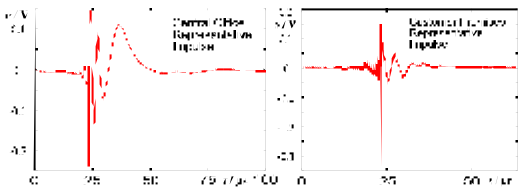

Figure 6. Representative impulses for central office and customer premises.

3 IMPULSE-NOISE GENERATOR

For impulse-noise modeling, we propose to use either the representative impulses of Fig. 6, which are especially useful for fast equipment tests, or a stochastic generator, which should be preferred for performance tests. The impulses represent the mean PSD and have some realistic shape due to the introduction of the typical phase function. Compared to our original proposal in [3], we simplified the generator structure (see, Fig. 7). It consists of three separate generators, each of which models the voltage, the length, and the inter-arrival time density, respectively. The beginning of an impulse event is triggered by the inter-arrival time generator and the length of an impulse event is determined by the length generator. Only during the impulse event, the voltage generator is active and supplies random voltage samples. The voltage sequence representing the impulse event may be windowed by a non-rectangular window of the length provided by the length generator.

The density of the voltage generator is given by Eq. (1) with a parameter u_0. Typical values for u_0 are 18 nV and 3 nV for central offices and customer premises, respectively.

The impulse-lengths are distributed according to the superposition of log-normal densities in Eq. (2) with the parameters

	Central Office	Customer Premises
B	0.25	1
s_1	0.75	1.15
s_2	1.0	-
t_1	8 µs	18µs
t_2	125 µs	-

The inter-arrival times are exponentially distributed: $f(t) = \lambda e^{-\lambda t}$. λ is the mean impulse rate. The mean impulse rate is proposed to be a variable parameter and should be less than 20 kHz.

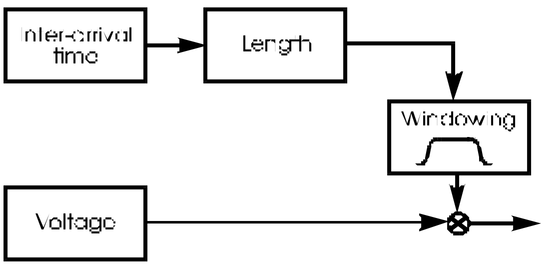

Figure 7. Block diagram of a simplified statistical impulse-noise generator.

4 CONCLUSIONS

We presented results of a recent impulse-noise measurement which has proven to have similar principal statistical properties as in our earlier campaign. From all results, we deduced a simplified impulse-noise generator and additionally two test impulses. Both alternative modeling approaches are proposed for designing and testing SDSL according to a desired impulse-noise immunity.

REFERENCES

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[2] Henkel, W., Kessler, T.: A Wideband Impulsive Noise Survey in the German Telephone Network: Statistical Description and Modeling. AEÜ, Vol. 48, No. 6, 1994, pp. 277-288.

[3] Henkel, W., Kessler, T., Chung, H.Y.: Coded 64-CAP ADSL in an Impulse-Noise Environment - Modeling of Impulse Noise and First Simulation Results. IEEE JSAC, Vol. 13, No. 9, Dec. 1995, pp. 1611-1621.

Corrections to [2] and [3]:

[2] Below Eq. (16), the γ_i have to be increased by 10 dB (90 instead of 80, 177 instead of 167, 80 instead of 70). The Parameters s_1 and s_2 in Eq. (12) and in Table 3 have to be divided by 10.24E6.

[3] In Eq. (6), 80 must be replaced by 90, and 167 must be replaced by 177. The Parameters s_1 and s_2 below Eq. (5) have to be divided by 10.24E6.