Experimental Diagnostics of Impulse Noise

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Abstract—The paper describes methodology of experimental diagnostics examining the influence of small home appliances in operation resulting in the injection of impulse noise into local communication lines. The most important result of practical experiments is a data bank of disturbing impulses that will serve for defining of impulse noise model.

Keywords–impulse noise; communication lines; local loop; electromagnetic compatibility

I. Disruptive Effects

There are many different sources of disturbance that can influence transmission properties of metallic lines in a negative way. If an access network is properly designed, the effects of internal system disturbances (mostly white noise of passive and active electrical components) are relatively small. Then the total information capacity of a channel will be limited mostly by external sources of disturbance [1], i.e.:

- Near-end crosstalk (NEXT),
- Far-end crosstalk (FEXT),
- Radio-frequency interference (RFI),
- Impulse noise.

While the first three listed types of external disturbance have been examined quite thoroughly, the study of impulse noise is not so usual. Therefore the purpose of this paper is to summarize practical experiments and evaluate the influence of possible impacts of impulse noise on metallic lines that are commonly used for high-speed data transmission in access networks.

The fundamental definition of impulse noise can be summarized as follows: Impulse noise is such type of disturbance that is randomly distributed in time and amplitude, and its amplitude exceeds the level of common (white) noise many times. The “quasi-impulse” noise also belongs to the same category; its difference against the “standard” impulse noise consists in the periodic appearance of disturbing pulses (or their bursts).

Impulse noise is very specific, and its level greatly depends e.g. on the place where the metallic line is laid. Its source is the electromagnetic radiation emitted by power feeding cables, high-voltage distribution lines and other installations and systems, especially during switching and regulation of high powers. Impulse noise is characterized by its short duration. It is formed by voltage peaks with steep leading and trailing edges, which often occur in bursts, causing so-called block errors in data transmitted over the disturbed lines [2].

II. Model Noise Pulses for Evaluation of Impulse Noise Influence

With respect to the described nature of impulse noise it is not easy to design an ideal methodology for evaluation of its influence on high-speed data transmission systems. The basic problem is the definition of a model describing the impulse noise that would be suitable for testing of the said systems.

ITU-T recommendation for testing procedures of ADSL systems describes test impulses 1 and 2 [3]. It also proposes the basic methodology to determine the influence of impulse noise on a system. The recommendation for HDSL defines Cook pulse.

Electromagnetic compatibility (EMC) standards describe specific bursts of pulses (European standard EN 61000-4-4).

There are also proprietary models for impulse noise, one of the most famous being that of France Telecom.

III. Experimental Measurements

A. *Introduction to Measurements*

Some specialized works such as [4] show that the xDSL systems are most critically influenced by impulse noise that is injected in proximity of the subscriber’s xDSL modem (ATU-R).

This will be the case of disturbance in the premises of xDSL subscribers, e.g. family houses or apartment buildings. Therefore we have chosen some very typical home appliances for testing of impulse noise effects.

The setup of our testing workplace corresponds to the scheme described in ITU-T G.996.1 recommendation [3] (with some minor modifications).

B. *Workplace Setup*

The proposed experimental workplace consists of a standard extension supply cable and a digital storage oscilloscope. There is a very close parallelism of the supply cable and the local metallic subscriber line, the length of which is 2 m (this value has been verified by numerous experiment and practical experience showing that for the lengths over 2 m the increase of the induced interference is minimal). On the near end there is a common type of symmetric phone cable terminated by a balanced-unbalanced transformer that is connected to the 50-ohm input of the digital oscilloscope (see Fig. 1). This way we can measure the impulse noise disturbing the supply networks and the telephone subscriber line.

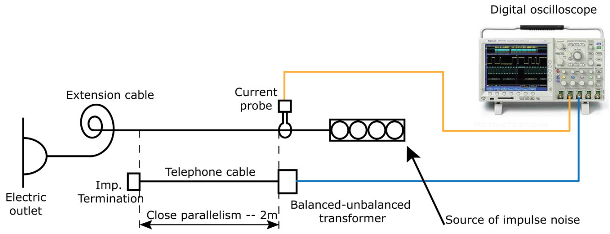

Figure 1. Setup of a workplace for impulse noise diagnostics.

Sources of impulse noise will be represented by home appliances plugged in the electric outlet. The parallel cables should be as straight as possible and far enough from other sources of possible interference.

IV. TESTING RESULTS

The testing was performed in five to six steps, depending on the specific device. The first step was always the measurement of disturbance without the respective appliance plugged, in order to minimize the bias in measured values. The total number of tested devices was 10; the extent of this paper allows summarizing of the testing results only for 3 of them, specifically:

- Universal charger HAMA,
- Handheld blender (SOFTmix ETA),
- High-speed drill with smooth regulation EXTOL (m. 404116).

In the idle condition during the experiment, the impulse noise was not observed at the oscilloscope input.

In the following figures the black curve represents the impulse noise in the supply network and the gray one the impulse noise in the telephone subscriber line.

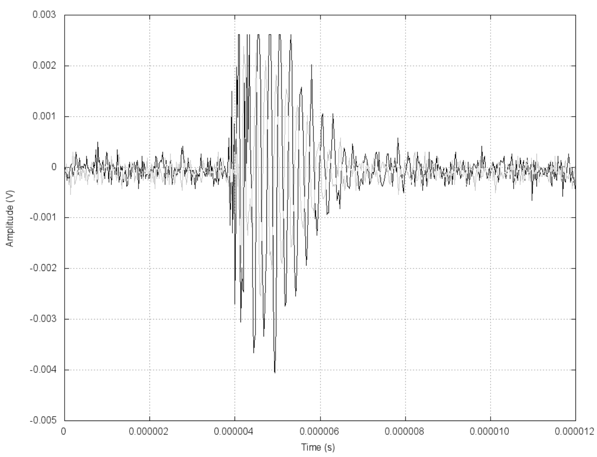

Figure 2. Batteries insertion.

A. *Universal Charger HAMA*

When the charger is plugged in, but without batteries, it does not produce any impulse noise. The behavior of the charging device is identical.

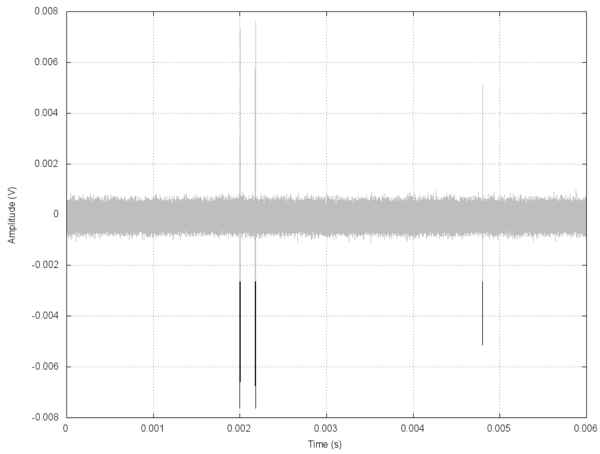

Figure 3. Batteries ejection.

From Fig. 2 and Fig. 3 it is apparent that the impulse noise occurs in connection with transition states – i.e. when batteries are being inserted or ejected. The resulting impulse noise can be described by the following formula:

$$x(t) = \begin{cases} \hat{A} \cdot e^{-\frac{(t-t_0)}{\tau}} \cdot \sin(2\pi f(t-t_0)) & t_0 \le t \le t_0 + t_{in} \\ 0 & else \end{cases}$$

B. *Handheld Blender*

The plugging of the blender into the power supply caused periodic disturbance in the telephone line. However, this interference cannot be considered as impulse noise since it is periodic and its nature can be analytically described. The probable cause of this phenomenon is that the built-in feed unit is permanently online (i.e. wrong design of the switching power supply). Although the noise is not the impulse one, it has to be taken into consideration when designing the protective circuitry of xDSL modems.

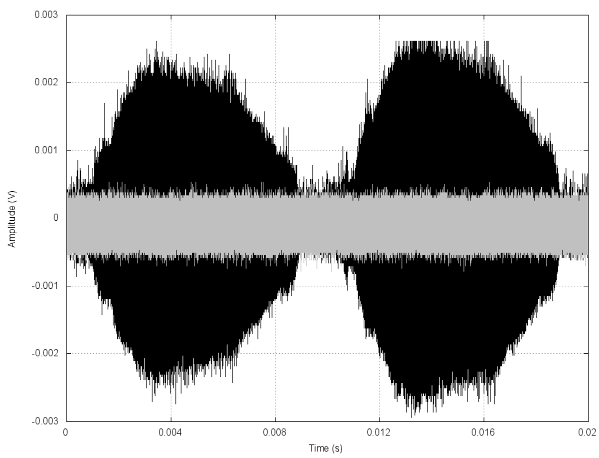

Figure 4. Blender plugged in.

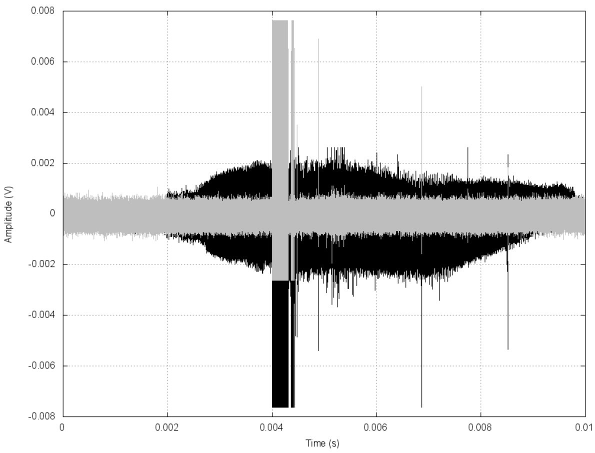

Figure 5. Figure 10. Startup of a blender.

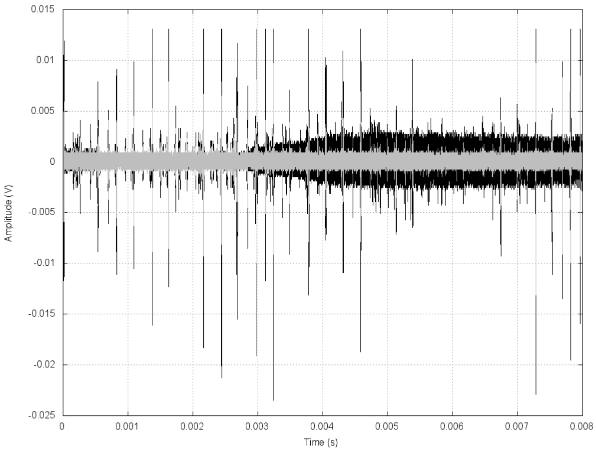

Figure 6. Blender running.

The effects of the impulse noise generated by the blender in the steady state during normal operation towards the supply network are relatively small; as for the telephone line, the nature of the noise is rather quasi-impulse.

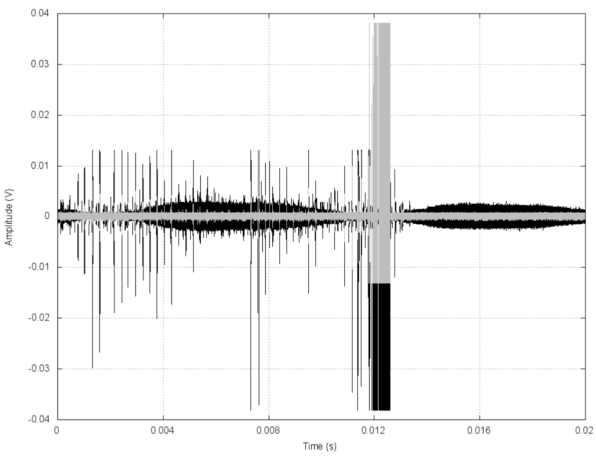

Figure 7. Shutoff of a blender.

The startup and shutoff of a blender generates extraordinarily heavy impulse noise.

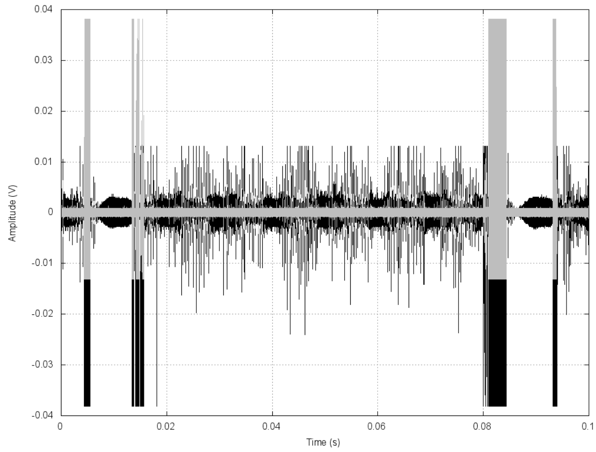

Figure 8. Switching of blender speeds.

The figures illustrating the impulse noise generated by the blender show that the noise is rather random, with very high amplitude.

C. High-speed Drill

When just plugged in to the supply network, the drill does not produce any impulse noise.

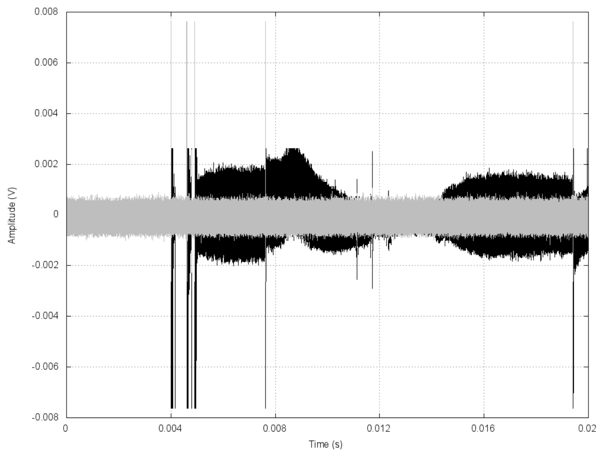

Figure 9. Startup of a drill.

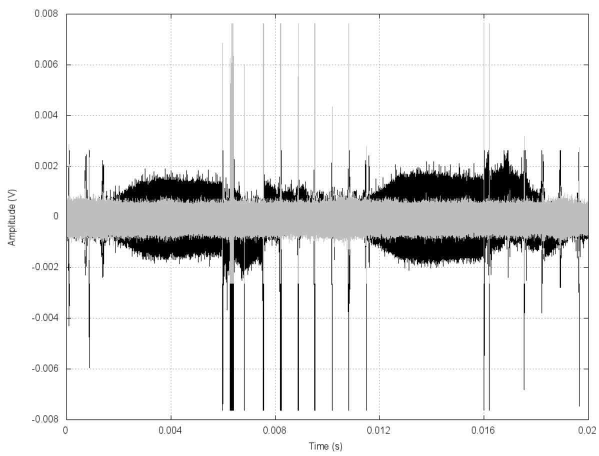

Figure 10. Drill running.

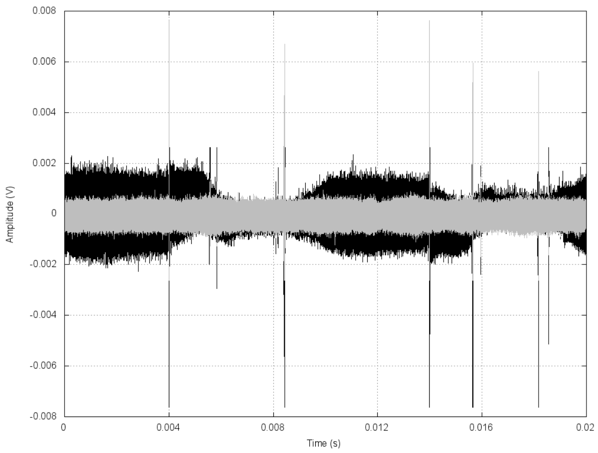

Figure 11. Drill speed regulation in operation – minimum power.

The highest values of impulse noise were obtained during the drill startup.

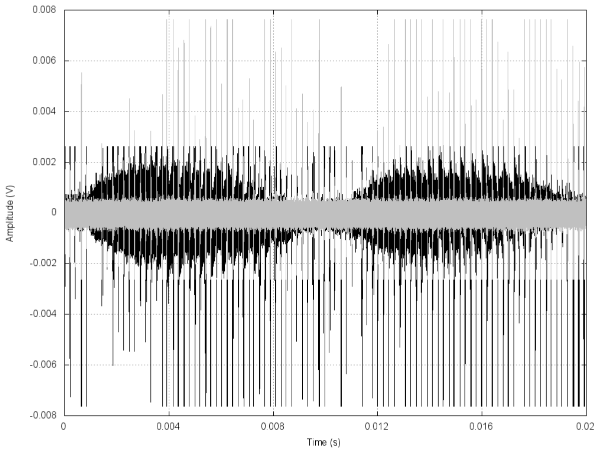

Figure 12. Drill speed regulation in operation – maximum power.

The most frequent occurrence of impulse noise can be observed during regulation of the drill speed with maximum power. This is probably caused by switching to faster speed and subsequent transient states that generate impulse noise, and the electromagnetic radiation then induces impulse noise also in the telephone line.

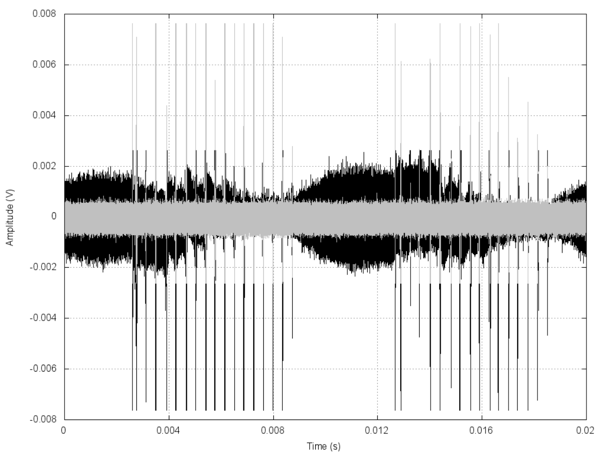

Figure 13. Drill speed regulation in operation.

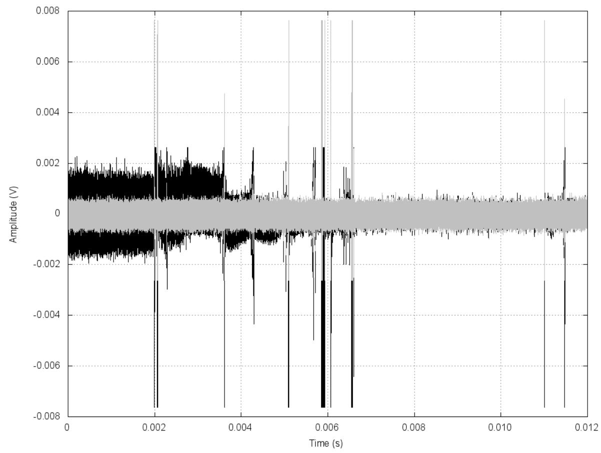

Figure 14. Shutoff of a drill.

V. Conclusion

The measurements have proven that it is difficult to describe the impulse noise using universal models that use precisely defined test impulses.

The disturbance generated by small home appliances shows the influence on symmetric telephone lines in close vicinity of power lines caused by penetration (injection) of the interference into the telephone line. The disturbance is closely related to transient states, i.e. startup and shutoff of appliances or changing of their operational state (e.g. power or speed).

The disturbance in xDSL systems can be eliminated – to certain extent – with the help of suitable protective mechanisms. Data transmission can be protected using Reed-Solomon (RS) coding and interleaving.

In our future work we will focus on effects of disturbance from small appliances on video transmission in xDSL systems (especially ADSL2+ and VDSL), with respect to the distance between the power line and the metallic subscriber line, to the distance of the appliance, and also to the length of the cables. The quality (or level of corruption) of the video signal will be evaluated using objective methods that are commonly used for quality assessment of video.

Acknowledgment

The paper was supported by the Czech Ministry of Education, Youth and Sports grant No. 6840770038.

References

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