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Fuzzy Handling of the Effects of Noise and Insertion Loss

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Abstract: In several areas – in absence of optical networks – telecommunications companies have to provide digital services with high data transfer rate using copper wire based cables of the telephone network. These telephone networks are not evolved for broadband communications technologies, thus, using them, current demands can be satisfied only within certain limits. These limits, e.g. the maximal available data transfer rate that can be reached by using a certain wire pair (line), have to be known by the service providers. The process which is used to produce this information is called performance evaluation (or prequalification). In this paper we represent a novel, fuzzy based performance evaluation method for SHDSL connections of telecommunications access networks which uses measured electrical line parameters and which reliability exceeds the reliability of other, generally used methods.

Keywords: *access networks, SHDSL, fuzzy systems, performance evaluation*

1. Introduction

Copper wire-pair based cables used in telecommunications networks are not the most modern items of the wired technologies, however, the gross of the world's whole telecommunications network consist of copper wire-pair based networks. The change of the metallic cables of access networks to modern, optical fibre cables are not only expensive but also time consuming. Existing copper networks will be operable at least even in the next decades without the need of any significant expenditure, so telecommunications

service providers are continuously looking for such technologies which can fulfil – at least partway – the demands of up to date, high speed digital data communication on these 'old type' networks. These technologies have two main types. The so-called fourth generation networks raise the data transfer rate (bit rate) by the reduction of the length of the copper wire-pairs.[1] In these networks the connections between the central office and the nodes of the access network are realized by optical fibre cables, while the subscribers and users are connected to nodes by the old metallic telephone cables. According to Ödling, these fibre-copper hybrid networks containing coper wire pairs will be used for creating new connections also in 2040. [1] Other, merely transmission technology based solutions are e.g. the members of the DSL transmission family, which were evolved definitely and solely for the usage in the copper wire based access networks. These continuously developing technologies provide higher and higher bit rate.

The bit rate of DSL connections on the lines in homogeneous copper and also in hybrid networks is variable. This variability means that the maximal available bit rate can be dissimilar at the endpoints of the network. In order to give proper proposals to customers, telecommunications companies have to have information about the available bit rate of the endpoints of their networks. In advance, without the installation of the equipments of the selected transmission technology, this data can be only predicted. The process of the prediction is the performance evaluation. Telecommunications service providers use various performance evaluation techniques which differ from each other also in expenses and also reliability.

In this paper we propose a novel performance evaluation method for one of the members of the DSL family, which is based on the measuring of electrical line parameters of the wire pairs, and predicts the available data transfer rate by fuzzy reasoning. This selected member of the DSL family is the SHDSL (Single Pair High Speed Digital Subscriber Line) transmission method, which is described by [2] and [3], and for the bit rate prediction Mamdani's [4] inference method is used.

2. The fuzzy system of the proposed method for performance evaluation

For our study, SHDSL transmission technology was selected. Although, this method is less frequently used as e.g. ADSL, its simple installability and configurability and the easy possibilities of its measurement make it definitely suitable for such studies. SHDSL itself is a symmetrical, digital transmission method. Using it, the data transfer rates of the download and upload are equal. The bit rate can be set off in 64 kbit/s steps up to the available upper limit which is 5.7 Mbit/s in the case of the variant was used in this work. The SHDSL method is evolved definitely for using on the twisted wire pairs of the traditional telephone network, thus its use in other type network is atypical. The

[1] This option is also known as FTTN (Fibre to the Node).

SHDSL aimed performance evaluation of wire pairs – due to the smaller prevalence of SHDSL systems – is not too advanced. Existing methods are based on the experience of the technicians who work with these systems, although also distance based methods are current. These latter ones uses the length and the diameter parameters of the line as inputs, however, these techniques are based on the attenuation which is calculated by the mentioned parameters.

Our work aimed to create such a performance evaluation method which reliability exceeds the reliability of the currently used methods, and is quite simple for being suitable for the performance evaluation of such, less frequent connections.

As during the performance evaluation of the wire pair (line) only the wire pair is available, so only that can be examined, the antecedents of fuzzy rule bases, which are the bases of the performance evaluation method, have to be searched among the electrically measurable parameters of the wire pairs. More than 150 wire pairs of five access networks were concerned in our examinations. We measured various electrical parameters of these wire pairs. Earth-symmetry, noise level of the line, insertion loss, line impedance and return loss parameters were measured.[2] For rating the results of the measurements, equipments of SHDSL were connected to each examined lines and also the maximal available bit rates were measured. In virtue of the measured bit rates five clusters were formed. These are the next.

Table 1. Clusters of data transfer rate

Cluster	***Range [kbit/sec]***
A	0 – 840
B	904 – 1544
C	1608 – 2440
D	2504 – 3144
E	3208 – 5448

Measured parameters were grouped by the clusters of Table 1. There was no correlation between the results of return loss, earth-symmetry and line impedance measurements and the reached data transfer rate, thus these parameters can not be the antecedents of the performance evaluation system. However, insertion loss (IL) graphs were bunched in the clusters.

Fig 1. shows some examples of the measured results of insertion loss.[3] The formation of the groups by the bit rates can be observed in the figure. It can be seen in the figure also,

[2]During the work, lines only in working order were used, pre-qualification of wire pairs being out of order makes no sense.

[3]Line parameters were measured up to 2 MHz in case of each examined line, but in this paper results are presented up to only 1.5 MHz, because the used SHDSL systems use the lower 1.5 MHz wide band of the frequency.

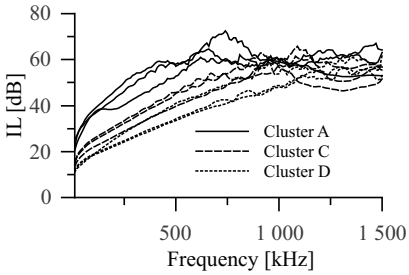
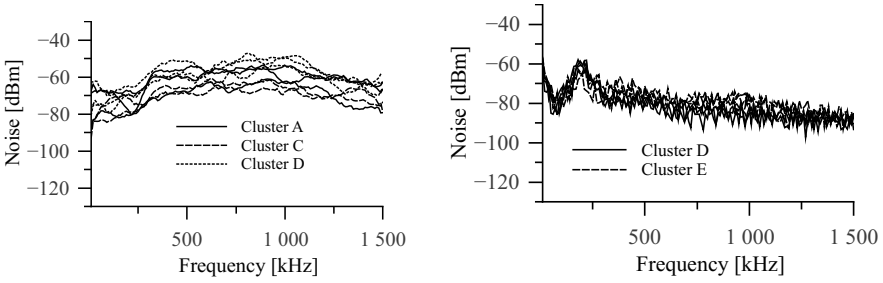


Figure 1. Measured Insertion Loss graphs of several lines.

that the bands of the several groups reach into or partially cover each other. This behaviour is shown by our measurements also in lower domains of the frequency, but towards the transparency of the figure, those results are not featured here.

According to [2], the quality of the transmission is influenced, beside insertion loss, also by noise. This is verified also by our measurement results, but during the work an interesting result was gained. In case of wire pairs belonging to the same geographical area the results of the noise measurements were not differing from each other, the separation which was observed in case of insertion loss was not repeated. During our work, in the respect of noise, more such homogeneous areas were differentiate. Examples of two of them are shown in Fig. 2. It can be seen in these figures that the graphs of the noise are independent from the available bit rate, the curves of each cluster are in the same narrow band.



(a) Noise shapes of area X

(b) Noise shapes of area Y

Figure 2. Examples of the noise in various geographical areas

With this behaviour of noise, joint usage of insertion loss and noise in the input side of the rules would result too difficult rule bases. The usage of hierarchical rule bases offers a more simple solution. As the noise is typical in singular areas, and – according to the

results of our measurements – its character is steady in a period of time[4], this parameter can be considered as a constant which is typical for the singular areas. This property gives possibility for the creation of area dependent rule bases which takes into consideration only the insertion loss values. Thus, on the first level of the hierarchy is the determination of the shape of the noise, than it is followed by the second level, where the insertion loss based rule base belonging to the determined noise shape is selected and used.

Insertion loss is a continuous line parameter in the frequency. In order to handle this continuous curve, six characteristic frequency were selected, which are suitable for the characterization of the whole insertion loss characteristics. The measured (and sorted into bit rate clusters) insertion loss values at these six frequencies were used as teaching samples for evolution algorithms [5] for the rule base construction. These six dimensional rule bases consist of ten rules and the membership functions of their fuzzy sets are trapezoidal. Fig 3. shows one of the rules as an example.

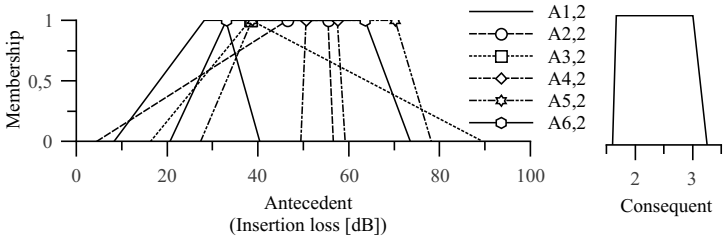


Figure 3. The 2^{nd} rule of a rule base.

As the output of the performance evaluation system has to be crisp[5], Centre of Gravity defuzzification method is used to create the final conclusion.

The reliability of this proposed performance evaluation method was compared to the reliability of other available methods. It was experienced that if the noise is not taken into consideration at all, and the evaluation is made only by the measured insertion loss values, the reliability of our method and the length-diameter based method is equalled. However, the reliability of our hierarchical method, which takes also noise into consideration, exceeds the reliability of the available methods. The results of the comparisons were published in [6].

[4]Repeating measurements were performed to find out the time dependency of the noise. It was experienced that – beyond a natural vibration – noise is steady during long periods.

[5]The number of a bit rate cluster.

3. Conclusions and future work

The wire pair performance evaluation method, which is presented in this paper, was made for SHDSL aimed pre-qualification of the copper wire pairs of telecommunications access networks, however, based on our recent results, its usage is successful also in case of the wire pair pre-qualification for other digital technologies. Its deep examination and validation is under way.

Although it was not preliminary planned, interesting observations were learned in connection with noise. In the next period we are dealing with further examinations of this phenomenon and the fuzzy based estimation of the shape of the noise.

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