THE PARAMETRIC MODEL FOR PLC REFERENCE CHANNELS AND ITS VERIFICATION IN THE REAL PLC ENVIRONMENT

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Summary For the expansion of PLC systems, it is necesssary to have a detailed knowledge of the PLC transmission channel properties. This contribution shortly discusses characteristics of the PLC environment and a classification of PLC transmission channels. A main part is focused on the parametric model for PLC reference channels and its verification in the real PLC environment utilizing experimental measurements.

1. THE PLC ENVIRONMENT

The PLC transmission environment is precisely presented in [1]. The noise scenario in this PLC environment is very complicated, since five general types of noise can be distinguished in power distribution line channels. These five types are following:

1. *Coloured background noise* – caused by a summation of numerous noise sources with low powers. Its PSD varies with the frequency in a range up to 30 MHz (significantly increases toward to lower frequencies) and also with the time in terms of minutes or even hours.
2. *Narrow-band noise* – caused by ingress of broadcasting stations. It is generally varying with daytimes and consists mostly of sinusoidal signals with modulated amplitudes.
3. *Periodic impulsive noise asynchronous with the main frequency* – caused by switched power supplies and AC/DC power converters. Its spectrum is a discrete line spectrum with a repetition rate in a range between 50 and 200 kHz.
4. *Periodic impulsive noise synchronous with the main frequency* – caused by rectifiers located in the power supplies operating synchronously with the main cycle. Its PSD is decreasing with the frequency and a repetition rate is 50 Hz or 100 Hz.
5. *Asynchronous impulsive noise* – caused by impulses generated by the switching transients events in the network. It is considered as the worst noise in the PLC environment, because of its magnitude that can easily reach several dB over other noise types.

Characteristics of the PLC transmission channel are dependent on features of the power distribution line network and on the line type. The PLC channel can be classified according to an available voltage as follows:

- *Channel with a very high voltage (VHV)* – this PLC channel has good transmission facilities thank to low noise levels and no-frequent failures on the line. Low noise levels are given mainly by a low number of connections that can cause reflections on the line due to imperfect matching of impedance. (Therefore, the multi-path effect can be neglected.) However, the VHV channel is not used as a data signal transmission line, only as a supporting line for bundles of optical fibers.
- *Channel with a high voltage (HV)* – this PLC channel is used for a data signal distribution in the point-to-point topology. The HV channel is not so good as the VHV channel, but its transmission facilities are almost maintained along the whole line length.
- *Channel with a low voltage (LV)* – this PLC channel is used for a data signal distribution in the point-to-multipoint topology. The LV channel is utilized for a power distribution in houses, flats, buildings, etc. In these locations, there are usually many points with imperfect matching of impedance. Therefore, the noise level can be increased and the information signal could be damaged. Also, the multi-path effect is self-evident.

Characteristics of the PLC transmission environment focused on the multi-path signal propagation, the signal attenuation, the noise scenario and the electromagnetic compatibility are introduced in [1]. The main part of this contribution is focused on the parametric model for various PLC reference channels in a real topology of power distribution networks.

The parametric model for the PLC channel is possible to adapt for any topology of the power distribution network. Parameters of this model with various coefficients were presented in ETSI

Technical Specifications TS 101 761-1 [2] and TS 101 475 [3] and a following set of reference channels for a practical utilization was established:

- *Reference channel 1 (RC1)* – a channel between transformer stations with features of the HV channel. A distance between separate transformer stations is around 1000 m.
- *Reference channel 2 (RC2)* – a channel from the transformer station up to the main circuit breaker, a distance is approximately 150 m.
- *Reference channel 3 (RC3)* – a channel from the main circuit breaker up to the counting box of consumed energy in the house, a distance is maximum 250 m.
- *Reference channel 4 (RC4)* – a home scenario.

The values of parameters like k, a_0, a_1, g_i, l_i (k, a_0, a_1 are attenuation factors, g_i is weighting factor and finally l_i means the length of i-th line branch) for the multi-path signal propagation can be found in [4]. Computer simulations at appropriate frequency characteristics of particular reference channels RC1, RC2, RC3, RC4 used values from a specific table. These frequency responses are graphically shown in Fig. 1, 2, 3 and 4.

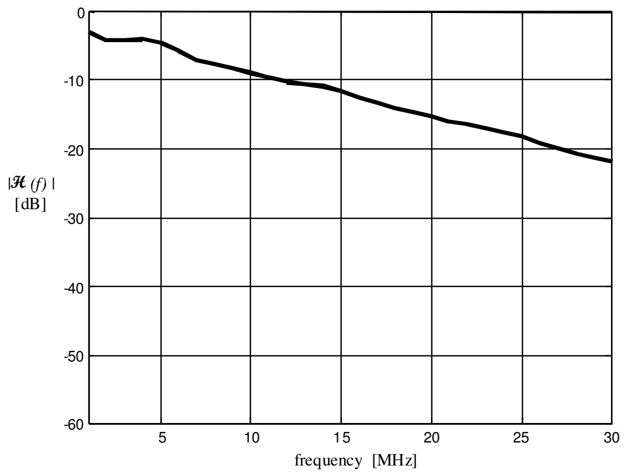

Fig. 1 The frequency response of the RC1 channel

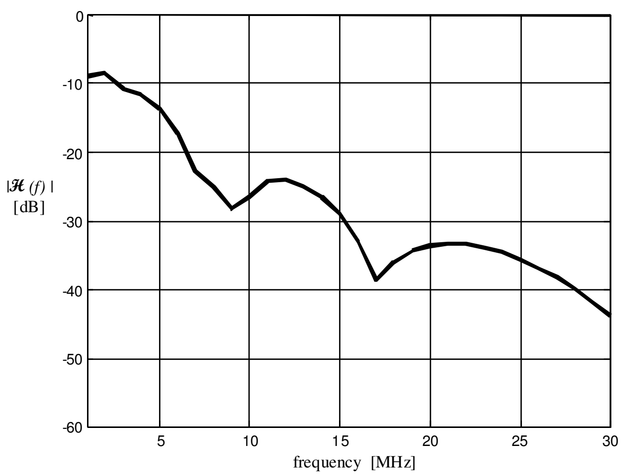

Fig. 2 The frequency response of the RC2 channel

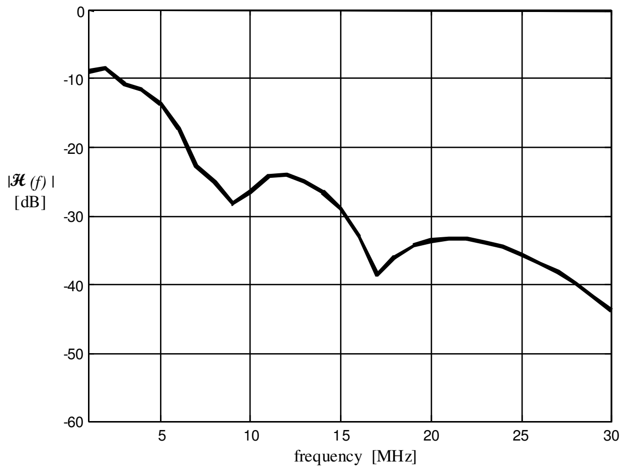

Fig. 3 The frequency response of the RC3 channel

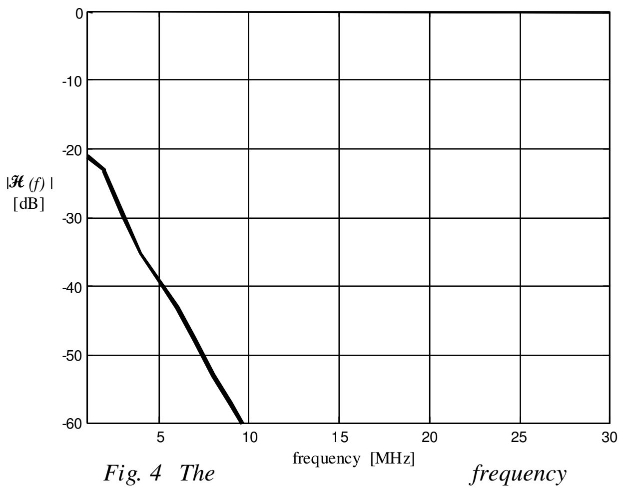

Fig. 4 The frequency response of the RC4 channel

2. EXPERIMENTAL MEASUREMENTS

For verification of defined values for the reference channel parameters, measurements on real PLC channels in following environments were executed:

- The 4-floor family house (3 phases)
- The apartment (1 phase)

We realized a measurement of the transmission channel characteristics and also a measurement of the channel throughput. At the transmitting side, the signal generator SMIQ from Rohde & Schwarz was used to generate signals with a frequency range from 1 MHz up to 35 MHz. At the receiving side, the network analyzer was located. Except these measuring accuracy devices, a capacitance coupler was used to segregate devices from the power distribution network. Needfulness for utilization of this coupler is outgoing from a demand to avoid the

50 Hz signal penetration into measuring devices and so to prevent wrong operations. In following parts, results from measurements in the apartment are presented in more details.

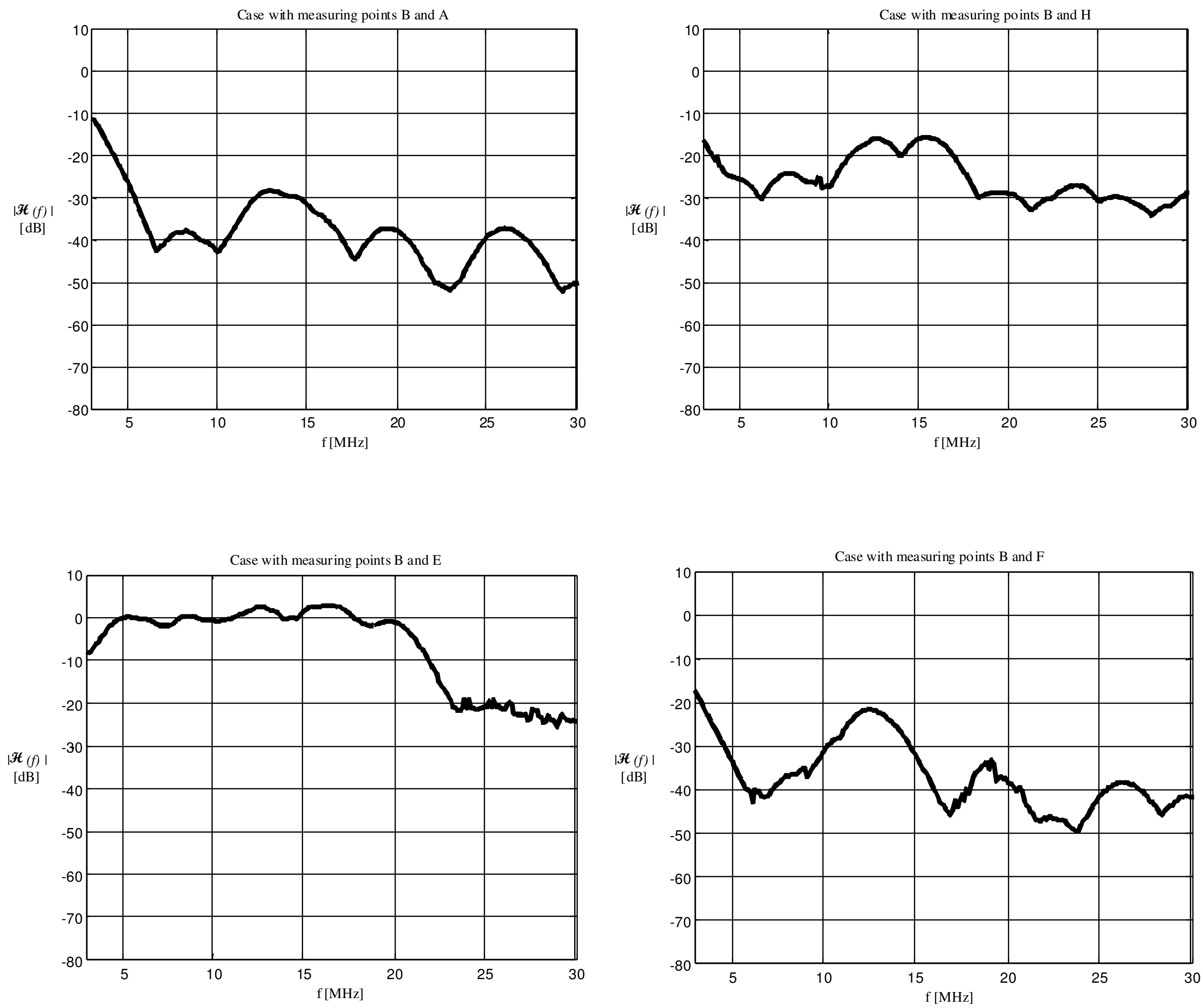

Fig. 5 Frequency responses between particular measuring points in the apartment

In the apartment, all rooms were connected to the same current phase. Differences between measuring points were caused by signal propagation paths and by bridged taps.

Measurements with correct results are presented on Fig. 5. Our measurements confirm assumptions that the signal attenuation is directly proportioned to the distance. In comparison with the 4-floor flat, distances between measuring points are shorter, therefore the signal attenuation is smaller. As in a case of the 4-floor family house, a majority of cases is very similar to those from the RC2 and RC3 reference channels.

3. CONCLUSIONS

We created the parametric model for PLC reference channels and consequently realized its verification in the real PLC environment utilizing experimental measurements. According with the transfer functions, it has observed the decreasing linear performance in the measured frequencies range where the number of imperfect matching points is minimum. Transfer functions have been measured in different electrical paths between measuring points in the 4-floor family house and the apartment.

It is necessary to conclude the great importance of a correct location planning of the PLC communication networks according to obtain a better performance of the PLC data transmission system. Results of our realized measurements can be used for verifying of the proposed PLC simulation model. After demonstrating its suitability for searching for the most appropriate digital signal processing techniques, which belongs to critical requirements of the development of the next generation PLC communication systems with higher data rates, it is possible to continue in a design and a realization of the extended PLC modem.

REFERENCES

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