OFDM model for power line communication

P. Mlynek, M. Koutny, J. Misurec

Abstract— The article presents a design of the power line communication model. This model is composed of communication model, model of power line and noise model. The communication model are realized as the OFDM system, power line are modelled from transfer function of a two-port network and a noise model are modelled as a white noise, which gets a spectral colouring by a filter. On the resulting PLC communication model was shown a comparison of different modulation technique and coding scheme.

Keywords—power line, OFDM, noise, modelling

I. Introduction

THE PLC technology (Power Line Communication) uses a power lines for data communication. PLC technology takes profits from the advantage of not requiring any additional wiring. There is a need to use distribution lines of electricity for the control signals, IP telephony transfer, and remote data acquisition [1]. It comes up almost simultaneously with electrical power network developing. This technology becomes more and more important. It is primary given with growing need of data channels using for s communication with meter equipments and control systems in energy industries. Its expansion is expected with AMR (Automated Meter Reading) and AMM (Automated Meter Management) systems coming. They are part of new metering and controlling trend co-called Smart Metering. The PLC technology should be as an alternative to other existing data channels [2].

There are a lot of failings for widely using of this technology. An interference of useful signal, smaller range of useful signal and equipments of energy network are the main. From the analysis of partial problems, there is a better to have a mathematical computer model of power line which it would enable a simulation of data transmission with power lines.

II. PLC communication system

For a creating of the complete PLC communication system, there is necessary to create model of channels as well as noise model and a transmitter and a receiver models. The complete PLC model will be created from particular models. There will be possible to create analysis of a concrete power line based on the simulations of this system with various models of lines. The analysis will be possible to judge in term of possibility to using of various combinations of PLC technologies, security transfer, modulations, coding etc. So that there will be obtained to best parameters of data transfer in mentioned systems.

It is necessary to create the channel models for the PLC simulation. There are more possibilities of power line model creating. First of them is the power line model as environment with multipath signal propagation. The parameters of this line are obtained from a distribution network topology or based on metering.

Second of them is model, which applies chain parameter matrices to describing the relation between input and output voltage and current by two-port network.

In design of PLC system, it is necessary to bear st. in mind the character of transmission medium and interferences which the PLC communication is influenced. It is necessary to find useable guard coders, modulation technique and encryption to ensure of security and foolproof communication with smallest error rate between data source and receiver.

The PLC communication system is possible to divide to particular parts for purpose of modelling:

- PLC communication model,
- Models of power lines,
- Noise model.

A. *OFDM model for PLC communication*

The model of PLC communication is created by a transmitter, receiver and channel block. It serves for a creating of a source and destination of data communication for subsequent simulations of lines model which they are replaced by block of channel. The basic PLC communication model with OFDM system is shown in the Fig.1 [3] [4].

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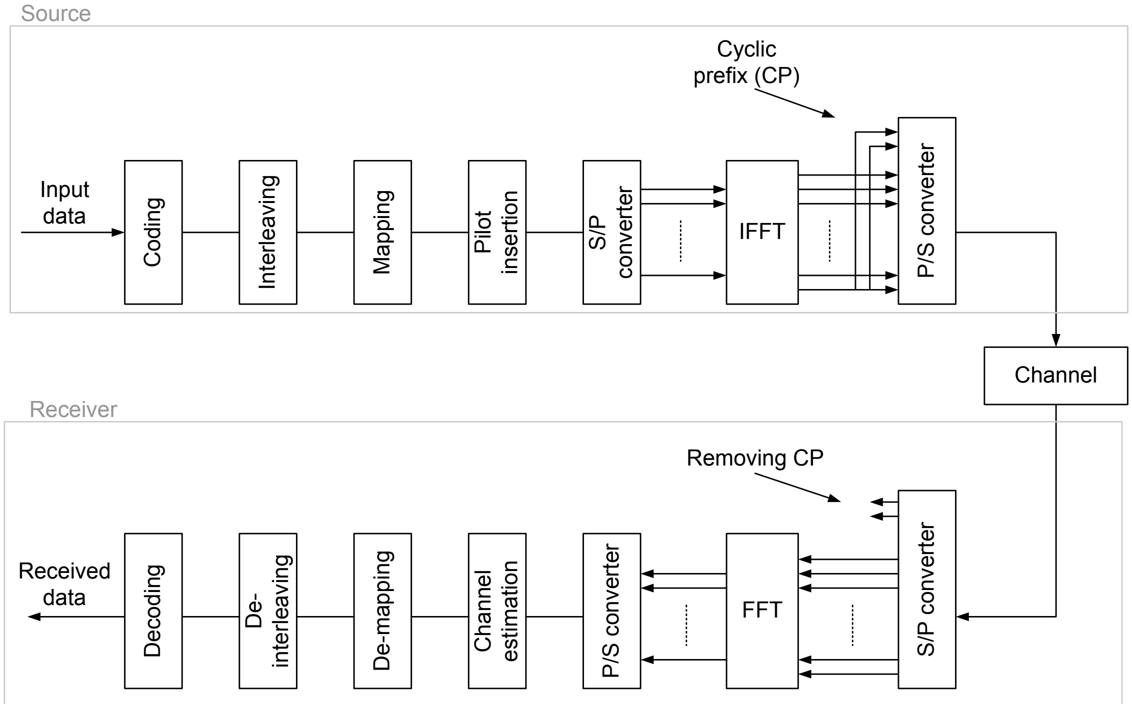

Fig. 1 The basic model of PLC communication with OFDM system

The coder adds the redundant information to the sequence of bits. If there is an error in bit chain the redundant information could be used for an error detection and correction by the help of detection and correction coders.

The scheme of coding is designed for detection and the correction independent errors. The scheme is not designed for the bulk of errors. The interleaving technologies are used for elimination of evolve of bulk errors during the transfer.

The serial data transfer is obtained from block of coding. This block is connected to a block of mapping. There is a transfer of bit sequence to a symbol sequence in block of mapping. A symbol distribution is a result of mapping. This distribution is shown in a constellation diagram and it is depended on chosen modulation.

The pilot signals are necessary to include to the transfer in case of continuous system detection. The estimation is important for determination of amplitude and phase of map's constellation each of subcarrier. The estimation of transfer channel in the OFDM system requests a inserting of known symbols or a pilot structure to the OFDM signal.

The useful data are transferred to the parallel stream in the S/P converter. The number of parallel streams matches to the number of carriers. These carriers will transfer useful data.

A protect interval is used in OFDM to prevent of ISI (inter symbol interference). A cyclic prefix (CP) is created by a few of last samples of OFDM symbols. CP creates a protect interval between adjacent transferred OFDM symbols in time area. This is a way how to keep orthogonally carries.

IFFT block transfers data from frequency to time area.

B. The sources of interference

Besides simulation of transfer characteristic, it is necessary to identify possible sources of interference because the power line has a significant attenuation of signal and various interference and noise. Therefore the data transfer has a high error rate without any checking algorithm.

In this paper, we deal with four different types of noise [5]*:*

Background noise: it is every time present in the network. It is caused by assembling of multiple sources of noise with low power. It can be described by a PSD (Power Spectral Density) that it declines with a growly frequency. The background power noise density can be described with equation:

$$A(f) = A_{\infty} + A_0 \cdot e^{\frac{-f}{f_0}} \quad (1)$$

where A_{∞} is power density for $f \rightarrow \infty$, and A_0 is a differences between $A(\infty)$ and $A(0)$. This model enables modelling background noise as a white noise process, which gets a spectral colouring by a filter.

Narrow-band noise: this noise primary originates from the broadcasting stations that they transmit in a long, middle a short wave range. The amplitude can be changed in dependence on time and place. The narrow-band noise can be modelled as a sum of multiple sine noise with different amplitude:

$$n(t) = \sum_{i=1}^{N} A_i(t) \cdot \sin(2\pi f_i t + \varphi_i) \quad (2)$$

where N is a number of waves of differencing frequencies f_i, amplitude $A_i(t)$ and phase φ_i. The amplitude $A_i(t)$ is a constant in simplest case but it can be established from broadcast transmission. The phase φ_i is randomly established from interval [0; 2π].

Asynchronous impulsive noise: this type of noise is characterized by high and short spikes of voltage with length 10 – 100 μs. These spikes can reach up to 2 kV level. This noise is the cause of the switching equipments in the distribution network. These kinds of noise are considered as a part of background noise.

Synchronous impulsive noise: is caused by thyristors in light dimmers and copiers. They are bursts of interference spikes with repeating of period. Synchronous impulse noise can be modelled by a source of white noise with a spectral colouring together with a periodical switching of rectangular wrap (Fig. 2).

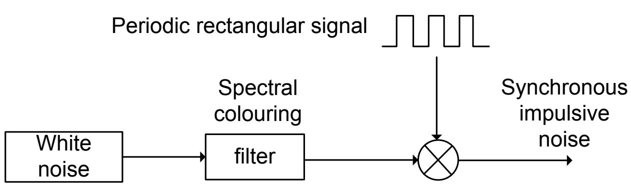

Fig. 2: Synchronous impulsive noise

C. *Power line model*

The power line model is required to simulate PLC communications. The power line model applies the methods used to model electricity distribution networks. The chain parameter matrices describing the relation between input and output voltage and current of two-port network can be applied for the modelling the transfer function of power line channel [6].

Modelling power line as cascaded elementary two-ports network enable working with elementary networks, two-ports, which can be described by cascade parameters. Cascade solution offers the possibility of choosing a certain degree of complexity and precision of the line being modelled. It is also possible to define individual blocks as macro models describing a data channel. An example can be seen in the solution given in [7]. Fig. 3 shows an example of cascade connected two-port networks.

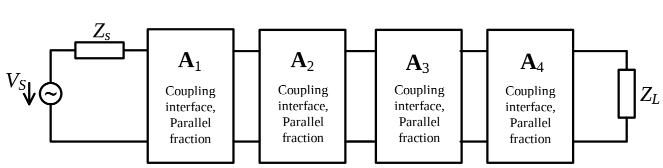

Fig.3 Cascade model of power line

Each part of the line is described by a separate cascade matrix $\mathbf{A}_1$ to $\mathbf{A}_4$. Internal series impedance $\boldsymbol{Z}_s$ of signal source $\boldsymbol{V}_s$ and parallel impedance of load $\boldsymbol{Z}_L$ can also be described by cascade parameters and included in the resultant transfer function. The resultant cascade matrix from the source to the load can be formed applying the chain rule:

$$A = \prod_{i=1}^{n} A_i \tag{3}$$

From the transfer function of power line model has been calculated the coefficient of filter and the power line channel has been modelled as a digital filter. The noises models have been modelled according to chapter B.

The power line model with noise model is shown in Fig.4. The particular noise has been made by a Simulink block's help.

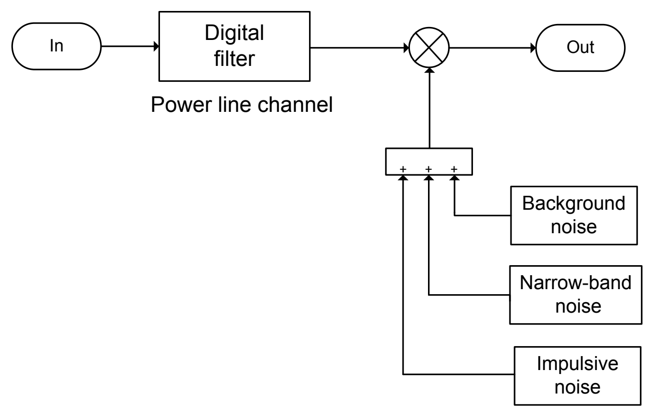

Fig. 4: Power line model

III. COMPARISON OF THE DIFFERENT MODULATION USING IN OFDM SYSTEM

The final model has been made from OFDM model and power lines model together with noises models in Matlab/Simulink [8]. The testing of various types of modulations and coding for data communication over power line have been accomplished on created model. Fig. 5 shows a comparison of the BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM modulations in OFDM system from the viewpoint of comparing bit error (BER) with the normalized signal to noise ratio (E_b/N_0). If we set the desired value $BER = 10^{-2}$, i.e. less than one faulty bit per hundred of the total value, that the desired value of normalized signal to noise ratio (E_b/N_0) are shown in Tab. 1.

TABLE I
DESIRED VALUE OF NORMALIZED SIGNAL TO NOISE RATIO FOR BIT ERROR $BER=10^{-2}$ FOR PARTICULAR MODULATION

Modulation	BPSK	QPSK	16-QAM	64-QAM	256-QAM
E_b/N_0[dB]	**4,7**	**7,1**	**10,3**	**14,8**	**19,2**

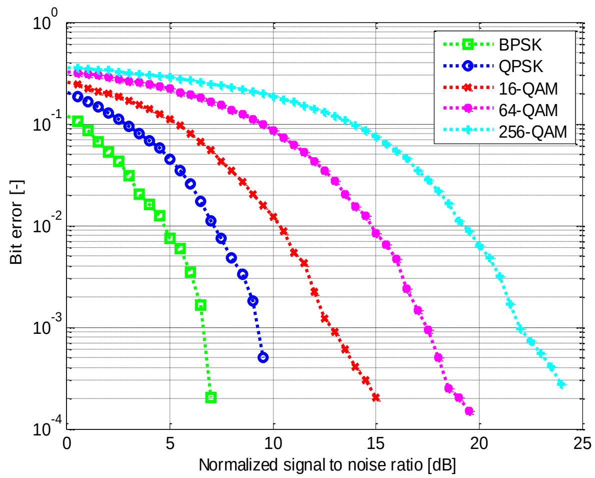

Fig. 5 BER dependence on E_b/N_0 for particular modulation in OFDM system

Fig. 6 shows the bit error rate (BER) dependence on the signal to noise ratio (SRN) with using of various types of channels coding for 64-QAM modulation. The best ability of correction achieves the convolution coder from used types of channel coding.

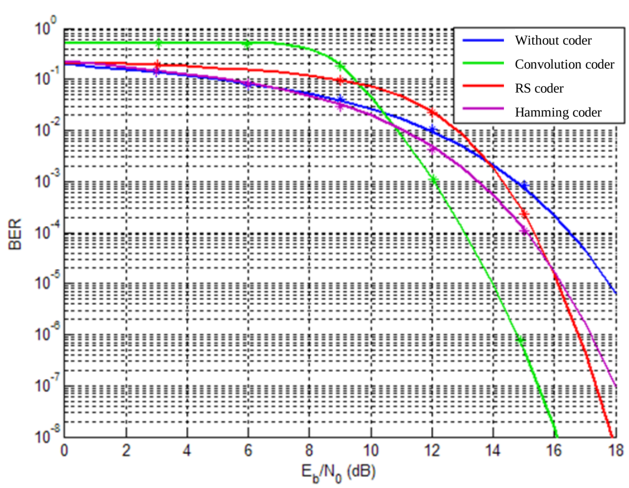

Fig. 6 BER dependence on E_b/N_0 for different coding scheme

IV. CONCLUSION

The article deals with design of the PLC communication system model. The model is composed of the OFDM communication model, the model of power lines and noise model.

The complex PLC communication model can be used for comparison of the performance of different modulation and coding schemes and for future standardization. The results of simulations based on the model will be compared with measurements in the future work.

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Petr Mlýnek (Ing. (MSc). in 2008 (FEKT VUT Brno) and was born on December 8, 1983. His master‘s thesis deal with testing security of the communication unit LAN of remote data acquisition against attacks from the Internet. Currently, he is a student at Ph.D. degree. His current research interests communication over the power line channel.

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