Channel Estimation of Power Line Communication using Back Propagation Algorithm

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***Abstract*-In the last few years a lot of research has been carried out in the field of deliverance of information for improving its efficiency and reliability. However, the systematic analysis and verification of channel performance triggered wide interest of new researchers. The popular technique for transmission of signals over wireless channels was orthogonal frequency division multiplexing (OFDM). In the present investigation, multilayer perceptron (MLP) based algorithm called back propagation algorithm has been proposed in power line communication. The present method (back propagation algorithm) is a OFDM based model which exploited for the channel estimation. Simulations on a realistic indoor power-line system show that the results obtained from the channel estimation using present model are significantly improved when compared with competitive neural network. It is also noteworthy to mention that the computational complexity is decreased using the present algorithm**.

Keywords-Power Line Communication (PLC), Neural Networks (NN), Multilayer perceptron (MLP).

I. INTRODUCTION

Power line communication (PLC) carries data on a conductor that is also used simultaneously for AC electric power transmission or electric power distribution to consumers. It is also called as power line carrier.

The different applications that need power line communications ranges from home automation to internet access. The two line nature of PLC includes: first one is the integration into wide area communication systems as the access part (i.e. the “last mile”) in competition with other technologies like Asymmetric Digital Subscriber Line (ADSL) wireless local loop or telephone line; the other is the use as Local Area Network (LAN) inside buildings or plants where we have to avoid new and complicated wirings. One of the main hindrances in modeling a good power line channel is the harsh and noisy transmission medium. Moreover, the power line channel is frequency selective, time-varying, and is impaired by colored background noise and impulsive noise. Furthermore, the wavelengths corresponding to the signals are comparable with the distances covered by a power line network and this requires the use of transmission line models to analyze the system.

The OFDM based system is used in power line and wireless communications. It has advantages as high-bit-rate transmissions over frequency-selective and time-variant channels.Several pilot-aided channel-estimation schemes have been investigated as reported In[1] for OFDM applications, and optimal pilot patterns for time variant, flat channels or time variant and frequency selective channels is proposed[2]. Blind channel estimation and equalization schemes have been proposed [3−5] for OFDM systems with high velocities and fast fading channels.

Power lines are very hostile channels for signal transmission. They show variations of time and frequency characteristics that can extremely reduce the efficiency of OFDM systems. Multipath models for Power line channels [6] require a priori knowledge on the cable parameters and an estimate of the power line topology to determine the number of sufficient paths to form the channel model. Such information are often difficult to obtain in-site, thus making these models not suitable for plug and play power line modems for indoor applications.

In the case of estimation using competitive Neural Network (NN) is a competitive NN with one neuron for each QAM symbol, in particular the case of QPSK is considered [7]. The redundant information reduces the influence of the impulsive noise and other disturbances improving the channel estimation. In this paper, multi layered perceptron neural network structures with the back propagation-learning algorithm are used to get CIRs for PLC [8].

II. POWER LINE CHANNEL MODEL

The determination of the transfer function of the power line is a non trivial task since it depends on a number of variables,topology, network, cable parameters and impedences of the terminated appliances.

A. Transmission Line Model

Various methods used to simulate and study the transmission line behaviour are described in [9–11]. Most of them are obtained from the time dependent telegrapher’s equations which are for the elementary line transmission cell.

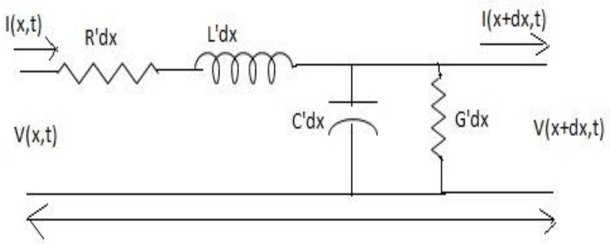

Figure 1. Elementary cell of a transmission line.

$$\frac{\partial v(x,t)}{\partial x} + R' i(x,t) + L' \frac{\partial i(x,t)}{\partial t} = 0 \qquad (1)$$

$$\frac{\partial i(x,t)}{\partial x} + G' v(x,t) + C' \frac{\partial v(x,t)}{\partial t} = 0 \qquad (2)$$

The Elementary cell of a transmission line is depicted in Figure 1. In the above equations *x* denotes the longitudinal direction of the line and R', L', G' and C' are per unit length resistance (Ω/m), inductance (H/m), conductance (S/m) and capacitance (F/m), respectively. The electric quantities are dependent on the geometric and constitutive parameters. Transmission lines are described using the characteristic impedance Z_c and the propagation constant γ:

$$Z_c = \sqrt{\frac{R'+j\omega L'}{G'+j\omega C'}} \qquad (3)$$

$$\gamma = \sqrt{(R'+j\omega L')(G'+j\omega C')} \qquad (4)$$

The characteristic impedance Z_c and the propagation constant γ are related to the per-unit-length parameters of the transmission line.It is supposed that the per-unit parameters depend on frequency as[12].

$$r = r_1; l = l_1 + l_2 / \sqrt{f}; g = g_1 f; c = c_{1,} \qquad (5)$$

B. Power Line Channel Modelling

The power line model is considered as a black box described by transfer function, the method for modelling the transfer function of a power line channel uses the chain parameter matrices describing the relation between input and output voltage and current of two-port network. In Figure 2, the relation between input voltage and current and output voltage and current of a two port network can be represented as:

$$\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} U_2 \\ I_2 \end{bmatrix} \qquad (6)$$

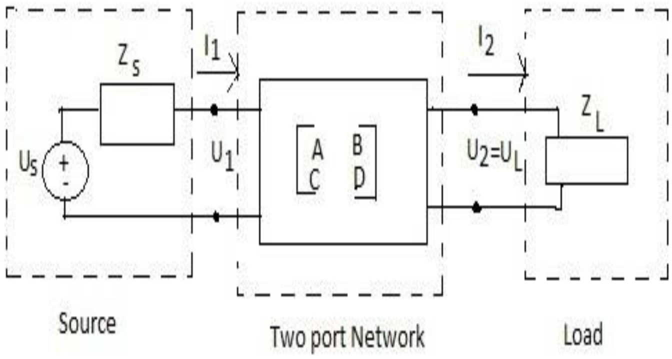

Figure 2. Two port network.

$$H = \frac{U_L}{U_S} = \frac{Z_C}{AZ_C + B + CZ_C Z_S + DZ_S} \qquad (7)$$

H is a transfer function of PLC channel. The ABCD matrix for the transmission line with characteristic impedance Z_c, propagation constant γ and length d can be calculated as [8].

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cosh(\gamma d) & Z_c \sinh(\gamma d) \\ Z_c \sinh(\gamma d) & \cosh(\gamma d) \end{bmatrix} \qquad (8)$$

B. Topology of the Network

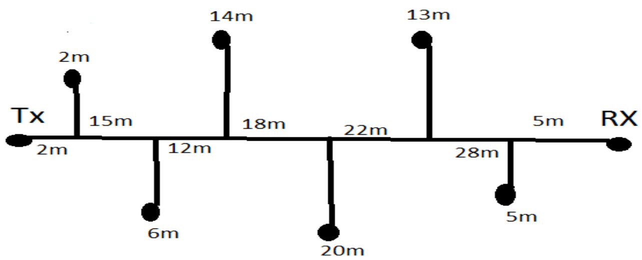

Figure 3.Topology of a realistic typical apartment indoor power line network.

Every link in the Figure 3 is a transmission line of length drepresented by 2X2 ABCD matrices.Resultant ABCD matrix is found by the multiplication of the all ABCD matrices as given for each link in the topology.

$$A = \prod_{i=1}^{n} A_i \qquad (9)$$

Where A is a ABCD matrix. We will get the transfer function response plot as shown in the Figure 4 for given topology.

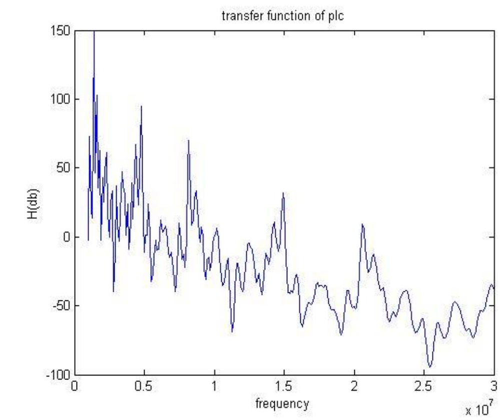

Figure 4.transfer function for indoor PLC.

III. SYSTEM MODEL

A typical block diagram of OFDM system model is shown in Figure 5. Binary data input is sent to the system and modulated using quadrature amplitude modulation (QPSK) then it is converted from parallel to serial. We are inserting pilot symbols which are used to get CIR.

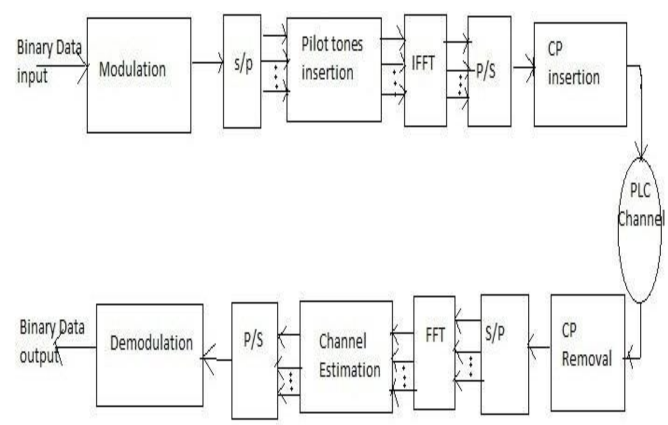

Figure 5.OFDM system model.

OFDM is a multicarrier modulation so in this modulation and demodulation is carried using Inverse Fourier Transform (IFFT) and Fast FourierTransform (FFT).After IFFT Cyclic prefix (CP) is inserted and then transmitted through power line channel and then CP is removed. Now converting it into parallel and finding FFT of the signal.

IV. BACK PROPAGATION ALGORITHM

In this paper, an MLP neural network structures with the back propagation-learning algorithm is used to get CIRs. This estimator is shown in Figure 6. As Figure 6 shows the proposed MLP network has two inputs, two outputs and ten hidden neurons. In order to adopt the neural network to OFDM, each complex signals are separated into real and imaginary parts. The OFDM symbols consist of complex signals whereas neural network uses real signals. Then the separated signals are inputted to the network and the outputs of the network will be the estimated for channel impulse responses. During real time operation of the estimator; real and imaginary parts of the signals are fed through the network and every units are computed in the network. This is done by computing the weights sum coming into the nodes and applying the sigmoid function[8].

The activation function of the hidden layer is:

$$net_j = \sum_{i=1}^{d} X_i w_{ij} \tag{10}$$

$$o_j = f(net_j) = \frac{1}{1+e^{-net_j}} \tag{11}$$

Where d is the number input units, X_i is input data to the network and w_{ij} is input-to-hidden layer weights at the hidden node j when we apply sigmoid function.Based on the hidden output signals Each output nodes computes its net activation as:

$$net_k = \sum_{j=1}^{h} o_j w_{jk} \tag{12}$$

$$o_k = f(net_k) \tag{13}$$

Where the subscript k indexes units in the output layer and h is the number of hidden units.

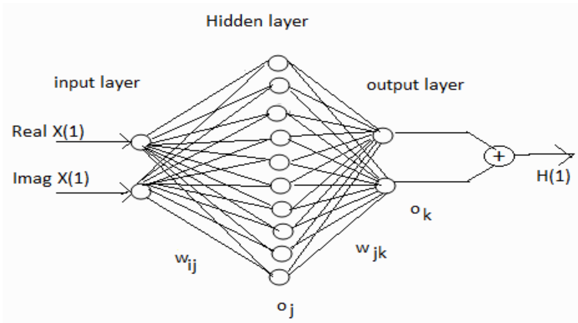

Figure 6. MLP structure for channel estimation.

In training process; weights of input-to- hidden layer w_{ij} and hidden-to-output layers w_{jk}, are found by minimizing

$$E(w) = \frac{1}{2}\sum_{k=1}^{a}(t_k - o_k)^2 \tag{14}$$

Wheret_k is k_{th} desired output and a is the number of output points. The back propagation learning rule is based on gradient descent The weights are initialized with pseudo-random values and are changed in a direction that will reduce the error:

$$\Delta w = -\eta \frac{\partial E}{\partial w} \tag{15}$$

where η is the learning rate that is chosen between 0 and 1. The learning rate η, determines to how much we change the weights W at each step. If η is so small, the algorithm will take a lengthy time to converge. Conversely, if η is too high the network is trained faster but we may end up bouncing around the error surface out of control – the algorithm diverges. This usually ends with an overflow error in the computer's floating-point arithmetic. So η was chosen as 0.05 in our simulations.

The weight update (or learning rule) for the hidden-to output weights are calculated as

$$\Delta w_{jk} = \eta (t_k - o_k) f'(net_k) o_j \tag{16}$$

The learning rule for the input to hidden weights is

$$\Delta w_{ji} = \eta [\sum_{k=1}^{a} w_{jk} (t_k - o_k) f'(net_k)] f'(net_j) X_i \tag{17}$$

The training process is finished when the value E of the goal is caught [8].

V. SIMULATION RESULT

Instead of using the BER (bit error rate), the following constellation error probability is used for performance analysis (Figure 7):

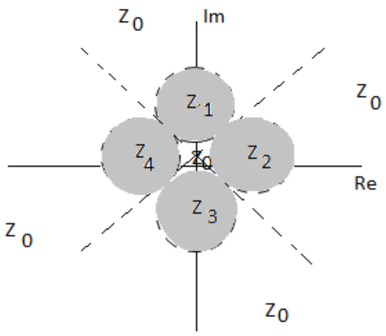

Figure 7. Boundary of the equalizer output constellation.

Probability of error rate is given by following equation:

$$P_{er} = \frac{N(Z_o)}{N(\sum_{j=1}^{4} Z_j) + N(Z_o)} \tag{18}$$

Where $N(\sum_{j=1}^{4} Z_j)$ means number of samples inside the shadowed area $N(Z_0)$ is the number of samples outside the shadowed area.

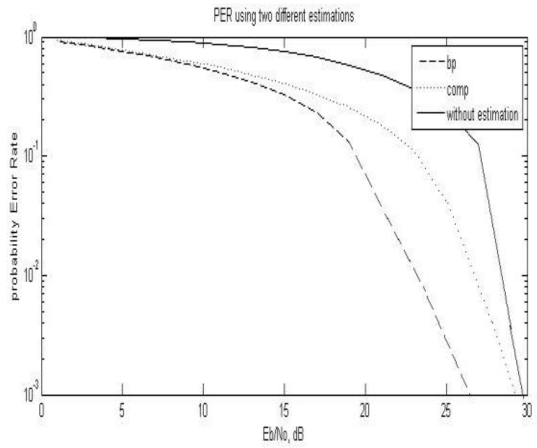

Figure 8. PER values for channel estimators.

As shown in the Figure 8., channel estimation using back propagation gives better result than competitive neural network.

VI. CONCLUSION

In this paper, a channel estimation method based on MLP neural network is proposed for PLC using OFDM system. In our proposal, those trained networks which are obtained after the networks are trained using channel impulse responses by an assistance of pilot symbols, are utilized as a channel estimator. As the networks are trained, the pilot transmission is not needed to be a different from other algorithms that get CIR based on pilot tones. So bandwidth is used efficiently. By observing simulation results, MLP neural network is better than competitive NN respect to PER. Besides the proposed MLP neural network has less computational complexity than competitive neural network.

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