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Power Line Communication Performance Channel Characteristics

Dipashree N. Duche, Vidya Gogate

Department of Electronics Engineering, Shah & Anchor Kutchhi Engineering College
dips_duche@yahoo.co.in

ABSTRACT

Power lines form the medium of transmission in PLC systems. The original purpose of these lines is the transportation of electric signals at 50 or 60 Hz .This paper proposes a new channel modeling method for power line communications networks based on the multipath profile in the time domain. The new channel model is developed to be applied in a range of Power line Communications (PLC) research topics such as impulse noise modeling, deployment and coverage studies, and communications theory analysis. The statistical multipath parameters such as path arrival time, magnitude and interval for each category are analyzed to build the model. Each generated channel based on the proposed Power line communication that a performance channel characteristic represents a different realization of a PLC network

1. INTRODUCTION

For conventional wired and wireless in-door data transmission there is growing need of data communications infrastructure. With the spread of Smart Grid concepts, power line communications (PLC) is in use for voice transmission technology since 1920s [1]. . It has become an attractive alternative for wired communication due to the development of robust modulation techniques of PLC channel. The methods of channel coding, and digital signal processing of PLC technologies has enhanced the use of PLC channel .This inspired to work on parameters which will explore the possibility of use of PLC in voice transmission.

2. PROBLEM STATEMENT

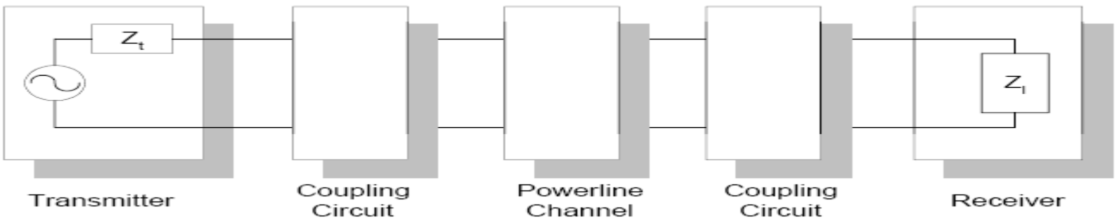
Statistical channel modeling method in the time domain is proposed for Power line Communication networks. The selected research area includes study of impulse noise, power delay Profile and communication theory analysis. Among potentially infinite series of reflection signals, it is difficult to evaluate the propagation Properties individually as the scale of the network goes on increasing complexity of measuring effect of impedance mismatches also increases. It required integrating the impact of varying topology into Statistical parameter such as power delay profile, path arrival time, path magnitude, impulse noise. This is done by proposed statistical model. The idea is to provide platform for the PLC network deployment, coverage Studies and communication theory analysis. Measurement of channel transfer characteristics is main Feature of the proposed PLC model, which helps to select accurate parameter of the signal propagation properties and the multipath effect.

3. POWERLINE COMMUNICATION TECHNOLOGY

The communication flow of today is very high. Many applications are operating at high speed and fixed connection is often preferred. Power line communication medium is cost-effective because it uses an existing infrastructure, wire exist to every household connected to the power line network. Power line communication is used for AC electric power transmission (frequency of 50 or 60 Hz) or electric power distribution to consumers.

3.1. POWER LINE AS COMMUNICATION CHANNEL

Channel is a Physical Path between transmitter and a receiver. In Fig-1 Digital communication system using power line as Communication channel is described .Important Parameter of communication are the output impedance Zt of the transmitter and input impedance Zl of the receiver. A coupling circuit is used to connect the communication system to the power-line. The purpose of the coupling circuits is two-fold. Firstly, it prevents the damaging 50 Hz signal, used for power distribution, to enter the equipment. Secondly, it certifies that the major part of the received/transmitted signal is within the frequency band used for communication.



This increases the dynamic range of the receiver and makes sure the transmitter introduces no interfering signals on the channel. [2]

FIGURE 1. A digital communication system for the power-line channel

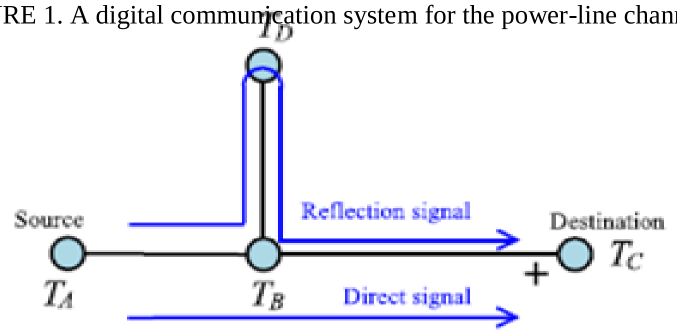


FIGURE 2. Multipath Propagation for a simple T type network

4. STATISTICAL CHARACTERISTICS OF THE PATHS IN MULTIPATH PLC CHANNEL

Multipath phenomenon lies in the heart of power-line communication and leads to the reception of multiple replicas of the transmit signal at the receiver through various paths. Statistical knowledge of arriving paths is essential to evaluate performance of communication systems.

4.1. SIGNAL PROPAGATION IN PLC NETWORK

a) Multipath channel propagation in PLC channel. When a signal passes through the tree from source to destination, the signal energy will be split by the branches at the junctions, and reflected at the branch terminations due to impedance mismatches. Thus, the received signal at the destination can be considered as the combination of the signal propagating through the direct path from the transmitter and a group of reflections from network branches. Here a simple T type topology network Fig 2 [5]
Fig. 2 Multipath Propagation for a simple T type network [5]
Theoretically, the number of reflection paths can be infinite [5]

Path 1: T_A□→T_B□→T_C

Path 2: T_A□→ T_B□→ T_D □→ TC□

Path *N:* T_A□→ T_B→ T_D.........→ T_B□→ T_C

5. PLC TOPOLOGY AND TRANSFER FUNCTION (Using Two Port Network)

The tree type topology of the PLC network is 1) in-door and 2) wide area network. The PLC network is in series of branches connected by backbone cables. Three components, namely cables, outlet (circles) and junctions (squares) are used to form a PLC network. Cables are used to connect the outlets and junctions. In this the cable types NAYY35 and NAYY150, which are widely used for indoor power distribution are used for outlet-outlet and inter-junction connections respectively. The junctions can be a derivation box in practice. The outlets can be an open circuit power socket or a socket plugged with an appliance. Reflection signals occur at terminals with open sockets or mismatched appliance

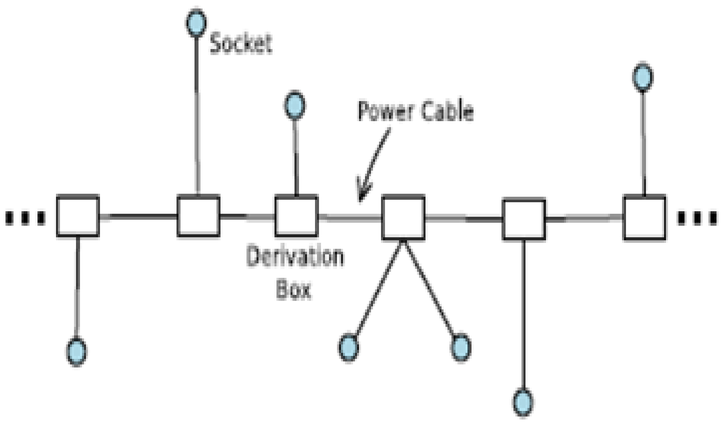


FIGURE 3. A typical network topology for the Statistical [3]

i) Voltage and current transfer characteristics of each segment (by using ABCD parameters)

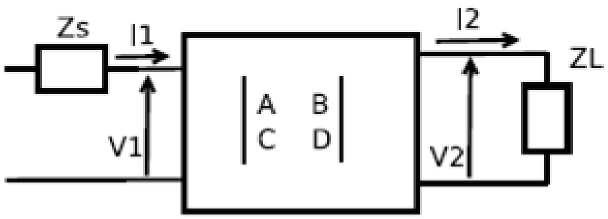


FIGURE 4. The ABCD parameter for a segment.[4]

The relations between the inputs and outputs of the 2PN in Fig.4

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} \cosh(\gamma l) & z_c \sinh(\gamma l) \\ \frac{1}{z_c}\sinh(\gamma l) & \cosh(\gamma l) \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \qquad (1)$$

Where, Tf is called the transmission matrix. Hence Transfer function of segment is [6]

$$H(f) = \frac{Z_C}{AZ_C + B + CZ_S Z_C + DZ_S} \qquad (2)$$

The transmission matrix of a shunt segment is:

$$T_S = \begin{pmatrix} 1 & 0 \\ \dfrac{1}{Z_{in}} & 1 \end{pmatrix} \qquad (3)$$

Where, z_{in} □= $\frac{A}{C}$□ □. Thus, the network consider□ □as a series of cascaded segments. After applying the Chain Rule (CR), the transmission matrix for the complete network can be calculated as:

$$T = \prod_{i=1}^{N} T_f^i \qquad (4)$$

Where, T_{if} is the transmission matrix of the i[th] segment.

6. ALGORITH FOR TRANSFER FUNCTION

For the obtaining channel transfer function against the frequency with the 40m distance, use the power cable, and select the properties of this cable

Steps 1) select the cable electrical property

```
μ0 =4π *10^-7 /* μ0 =Free Space Permeability
sigma=58*(10^6);
a=0.002;          /*a=Space between the adjacent conductor
d=0.07;
εr=4;        /* εr=Relative Permeability
ε0=8.854*(10^-12); /*Free Space permeability   [6]
```

Step 2) The lumped parameter Resistance (R), Capacitance(c), inductor (L) can be computed as below,

R=(sqrt((ur*u0*fin)/(pi*sigma*(a^2))))*(x/(sqrt((x^2)-1)))

L= $\left(\frac{\mu_r \mu_0}{\pi}\right) * \operatorname{a\,cosh}(x)$

C= $\frac{(\pi * \varepsilon_0 \varepsilon_r)}{(\operatorname{a\,cosh}(x))}$ [6]

Step 3) Angular frequency

$\omega = 2\pi f$

y=R+jω*L

Z=G+j$\omega * c$

Characteristics Impedance,

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$$z_c = \sqrt{\frac{y}{z}}$$

Propagation constant is calculated as,

$$\gamma = \sqrt{y * z}$$

Step 4) choose the path distance (40m)

The ABCD matrix for the transmission line and propagation constant and length calculated as

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} \cosh(\gamma l) & z_c \sinh(\gamma l) \\ \frac{1}{z_c}\sinh(\gamma l) & \cosh(\gamma l) \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix}$$

Where A= $\cosh(\gamma l)$,…&..D= $\cosh(\gamma l)$ [4]

Step 5) Transfer Function of two port network is given by

$$H(f) = \frac{Z_C}{AZ_C + B + CZ_S Z_C + DZ_S}$$

Step 6) Compute the angle and magnitude of transfer function

$$\theta = < H$$
$$dbH = 10 * \log(r)$$

7. Characteristics for the Transfer Function

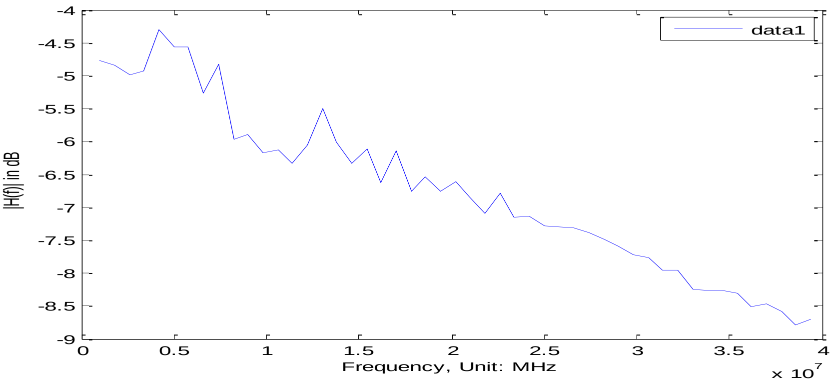

FIGURE 5. An example of channel transfer function against the frequency

8. METHODOLOGY OF TIME DOMAIN CHANNEL MODELLING

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For multipath channels, the number of available paths, the magnitude and delay profile of each path, and the phase of the feature path are often consider in the time domain to form the channel

8.1. PATH SELECTON

There should be infinitely many paths in a single channel impulse response. In order to extract the path features, herein only paths with a magnitude which is larger than a certain threshold (20dB below the maximum peak magnitude,

b) Channel Cluster: It is group of number of channel

i) Distribution of the number of paths

By observing a group of channels of a certain class (except Class [because the channels belonging to Class I are single impulses in the time domain without reflections, which means that there is only one path which is the maximum magnitude channel in Class I.]I) in a cluster, the path number for this group shows a Gaussian distribution which can be also seen in other classes of other clusters. Thus, 2 parameter sets, μi,k and σi,k (i = 2, 3, 4, 5), can be used to describe the number of paths for the ith class the of kth cluster. The trends of these parameters as a function of cluster number (i.e. distance) can be seen in Fig. I and Fig. II
The number of the paths for the channel of the ith Class and the kth Cluster can be described by equation which is a Gaussian distribution:

Ni,k = _N(μi,k, σ2i,k) _ [5]

Where [·] means to round towards the nearest integer, parameters μi,k and σ2i,k are the expectation and standard deviation of the Gaussian distribution. The value μ and σ in each Class increase as power function of Cluster Index. The Power function can be written as:

μi,k = pi1kpi2 + pi3 (2)
σ2i,k = qi1kqi2 + qi3 [6]

c) Magnitude features of paths:

- The magnitude of the path typically decays as the time delay increases. In a multipath communications channel, this relationship is called the power delay profile (PDP).
- The magnitude of the path depends on the how far the signal travels through the network.

In figure no. I double exponential functions are used to fit the magnitude decay with the cluster index. The main path in Class I arrives at the destination without reflections. Thus the first arrival path magnitude for Class I purely depends on the attenuation. Fig no.II. The Parameters Expectation, Variance, “for the time Interval plotted as a function of Cluster Index Fig no. III. The mean path number plotted as a function of cluster index which indicates the transmission distance. Fig. no.IV The variance of the path number plotted as a function of cluster index which indicates the transmission distance.

Fig .no.I Magnitude Decay for the first arrival path as a function of cluster index which indicates the transmission distance.

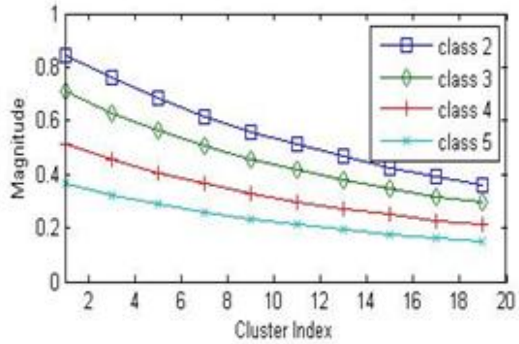

FIGURE I

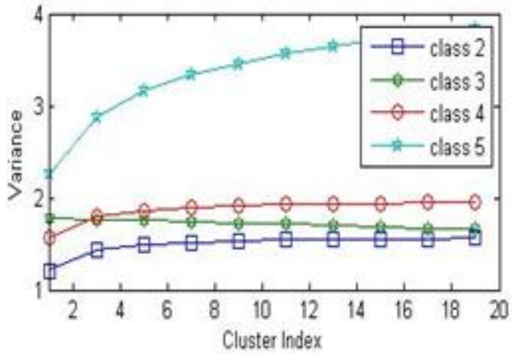

FIGURE II

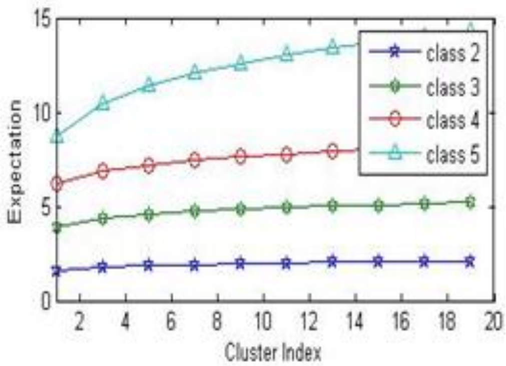

FIGURE III

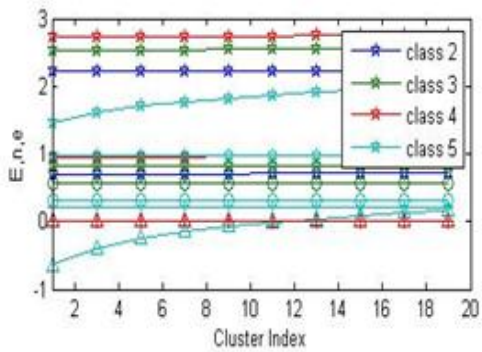

FIGURE IV

d) Power Delay Profile of Other Paths:

Paths experience random reflection and delay in the other classes, thus the magnitudes for these paths do not show step change features. Thus, for these paths, only the magnitude characteristics of the propagation distance (cluster) is investigated. The average magnitudes of different classes within a cluster present very similar decay features, thus, in this paper we do not study the magnitude differences between classes.

The average magnitude decay trends of these paths also can be described by double exponential functions, Due to the random signal reflection behavior through the network, the magnitudes of these paths follow a Rayleigh fading distribution. Rayleigh samples are used to generate different network realizations, the channel for one network is considered to be static with time

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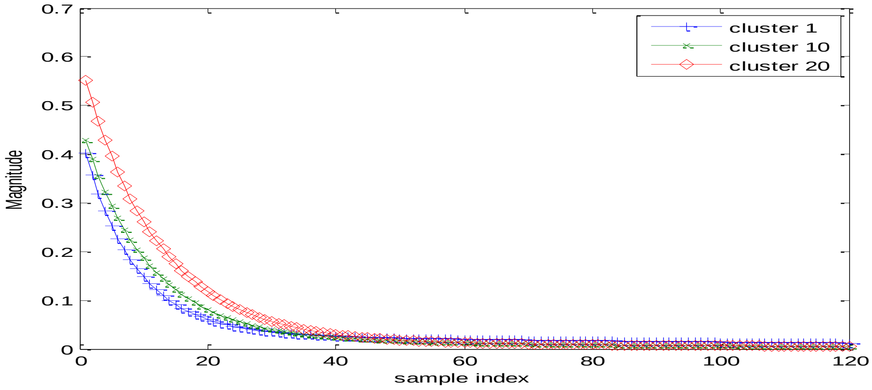

FIGURE 6. Average Magnitude VS time delay of Cluster 1, Cluster 10 and Cluster 20

9. ANALYSIS OF IMPULSE NOICE

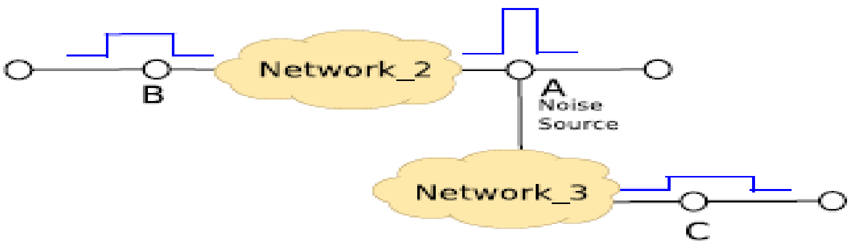

FIGURE 7. Impulse Noise Spread Model in PLC Network [5]

Impulse Noise: Impulse noise in PLC: (i) Periodic: noise which is caused by power converters in power supplies and by rectifiers operating in the alternating voltage current network. (ii) Aperiodic: Sources for aperiodic impulsive noise are switched power supplies, the turning on/off of appliances. Simulation of the impulse noise is done by Markov chain.

Power Cables use for the propagation of the impulse noise in PLC network. In fig5 impulse arises at Socket A due to the switch on/off of this socket. After spreading to Socket B and Socket C through Network 2 and Network 3, the impulse magnitude will be reduced, while the delay spread will increase. Thus, Correlated impulse noise model is necessary for more realistic signal propagation PLC. Assume Socket B and Socket C are the transceivers and Socket A is the relay node for the bi-directional data transmission protocols.

In the bidirectional scenario, both data transmission and reception will be disturbed when the impulse noise arises, since the impulse noise will propagate simultaneously with the signal. Thus, the paper of impulse noise is particularly important for capacity evaluation of bi-directional relay protocols in PLC networks. Also, with a more realistic impulse noise, high performance noise cancellation schemes could be developed which exploit knowledge of the correlation of the impulse noise

10. CONCLUSION AND ROAD AHEAD

The idea is to use proposed statistical model for communications theory evaluations and correlative impulse noise modeling in PLC networks. Statistical channel modeling method in time domain is proposed for PLC networks. First the channels are sorted into different categories based on such as point to point distance and the magnitude of the first arrival path .Second multipath parameter such as path magnitude and path interval are extracted to build the time domain impulse response. Shannon capacity theorem stated here,

$$C = B\log_2\left[1+\frac{S}{N}\right] bits/\sec$$

C=Channel capacity, B=Channel bandwidth, S=Signal Power, N=Noise within the channel bandwidth. can be derived for proposed statistical model this in terms confirm ,that as feasible model for PLC. The proposed Power line communication that Performance channel characteristics will be useful in the study of deployment ,coverage are our result of the transmission line method the proposed model will come out to better model to capture the path delay and average attenuation accurately. In PLC topology branch density may vary for each path magnitude and path interval due to this research study of different power grids will become important.

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