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RESEARCH-ARTICLE

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Simulation of Some Factors Influencing the Transfer Function of PLC Network

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ABSTRACT

Power line communications (PLC) network is one of the promising communication technologies for data transmission and information exchange in indoor distribution networks, because it does not require any new wiring installations, which can significantly reduce the deployment costs. This network is a practical solution for connecting all computer and multimedia devices to each other and to the telecommunication network, but there are still several problematic areas in data transmission over power lines cables. The power line channel is harsh environments for signal transmission. Indeed, many factors influence the communication path and path losses. These factors include the cable type, loading conditions, impedances, the types of devices or appliances connected to them. In this work, we focus on investigating these factors via simulations results of the transfer function of the indoor PLC channel. In addition we study the effect of line, branched line length, the number of branched, and impedance of devices connected to the PLC network on the performance of PLC Technology.

CCS CONCEPTS

• Computing methodologies • Modeling and simulation • Simulation types and techniques

KEYWORDS

Indoor PLC channel, Transfer Function, Impedance of Devices.

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1 Introduction

When moving to a new house, most people would likely to choose Wi-Fi to get the network as laying cable in the house is too complicated and makes the room messy. However, the wired network is faster and secure for internet access, file sharing, media streaming, online gaming and other things. So comparatively, the wired network is better than the wireless. Therefore we can use the indoor electrical network that finding in any every building. In fact this medium (electrical network) was designed for distribution of electrical power, not for data transmission like Internet access, multimedia communication or control command etc., to overcome this obstacle the PLC (power line communication) technology can provide appropriate solutions. Thanks to this technology is become of easier to use of present power networks without adding a single new cable. Just plug the device into a socket-outlet and one is instantly linked to the Internet.

The application of communication over the power transmission line is a quite old practice. From several years' power utility companies have been applying these networks for data communication purposes, measurements, control, monitoring and regulation of power plant and distribution network operation. Therefore, the low voltage power-line communication turns into a very interesting field of research[1]-[2].

Thus, to characterize a power line channel, it is very important to accurately estimate the distributed parameters of an electrical line. The various factors that influence the channel parameters are Skin effect, proximity effect, type of wiring used, wiring geometry in the cable, coupling effect, loading impedance, apart from the weather conditions which is difficult to simulate, etc. All of the effects mentioned above have been studied in previous research. In this paper, we will study the effect of line length from transmitter to receiver, branched line length, number of branched and impedance of devices connected to PLC channel.

The methodology presented here focuses on frequencies between 1 and 30MHz. In the second section, we will analyze the channel transfer function calculation. The third section will present the simulation results that is obtaining by the MATALAB simulators, where we will present the simulation results on the effect of various next factors. Finally, section four discusses the result and analysis as the conclusion of this paper.

2 Channel transfer function

1.1 Transfer function modeling

Several approaches for modeling the transfer characteristics of power lines can be found in literature. In this paper we will use the model [3]-[4]-[5] it is possible to calculate the transfer function as ratio between load voltage and source voltage using the equation:

$$\mathrm{H(f)\ in\ dB} = 20\log_{10}\left|\frac{Z_L}{AZ_L + B + CZ_SZ_L + DZ_S}\right| \qquad (1)$$

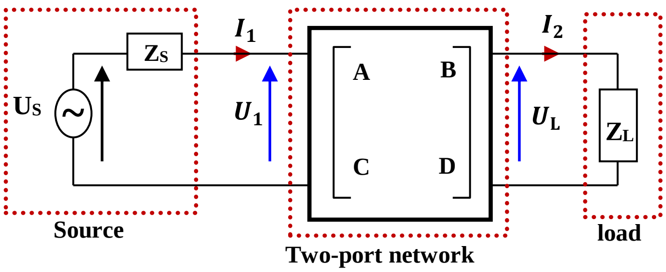

Fig.1: two-port network model

A, B, C, and D are frequency dependent coefficients that are calculated from the secondary parameters: characteristic impedance Z_C and propagation constant γ:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cosh(\gamma L) & Z_C \sinh(\gamma L) \\ \frac{1}{Z_C}\sinh(\gamma L) & \cosh(\gamma L) \end{bmatrix} \qquad (2)$$

The four intrinsic parameters obtained from (8) to (11) are considered to determine the ZC and γ.
The Characteristic impedance is given as:

$$\boldsymbol{Z_C} = \sqrt{\frac{\boldsymbol{R + j2\pi f L}}{\boldsymbol{G + j2\pi f C}}} \qquad (3)$$

and the propagation constant is given by :

$$\boldsymbol{\gamma} = \sqrt{(\boldsymbol{R + j2\pi f L})(\boldsymbol{G + j2\pi f C})} \qquad (4)$$

The transmission matrix for the serially connected impedance Z is given by:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \qquad (5)$$

and the transmission matrix for the parallel connection of load impedance Z_x is:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_x} & 1 \end{bmatrix} \qquad (6)$$

The branch cable terminated by the load impedance Z_l can be considered to be an equivalent load impedance Z_x :

$$Z_x = Z_S\frac{Z_l + Z_0\tanh(\gamma L)}{Z_0 + Z_l tanh(\gamma L)} \qquad (7)$$

The channel from a source to a load may consist of several network sections having different cabling, branch cables and loads connected in parallel. Each section can be described with a single transmission matrix. The sections are serially connected. The transmission matrix T from the source to the load can be formed by applying the chain rule [4]:

$$T = \prod_{i=1}^{n} T_i \qquad (6)$$

Where n represents the total number of network sections.

1.2 Primary parameters of power line

The line can be described by using R, L, C, G parameters. These parameters denote a resistance, inductance, capacity and leakage relative to the length of the line. Let's consider a single-phase signal distribution and management structure which is shown in Fig 5. The wire line includes phase, neutral and ground wires where each wire is inserted into the insulating sleeve and all wires are insulated with own sheath.

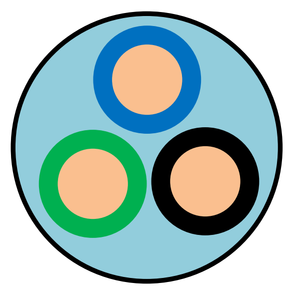

Fig.2 : Three-wires cable's cross-section

For the purpose of modeling, we consider the three-phase line as the two conductors and one transmission conductor, which they are a conductive core and they are surrounded by the same dielectric material. Then it is possible to determine the primary parameters with the equations [6]-[7]-[8]:

$$\boldsymbol{R} = \sqrt{\frac{\boldsymbol{\mu_0\mu_r f}}{\boldsymbol{\pi\sigma r^2}}}\left[\frac{\frac{\boldsymbol{d}}{\boldsymbol{2r}}}{\sqrt{\left(\frac{\boldsymbol{d}}{\boldsymbol{2r}}\right)^2 - \boldsymbol{1}}}\right] \ (\boldsymbol{\Omega/m}) \qquad (\mathbf{8})$$

$$\boldsymbol{L} = \frac{\boldsymbol{\mu_0\mu_r}}{\boldsymbol{\pi}}\boldsymbol{cosh^{-1}}\left(\frac{\boldsymbol{d}}{\boldsymbol{2r}}\right) + \frac{\boldsymbol{R}}{\boldsymbol{2\pi f}};\ (\mathbf{H}/\boldsymbol{m}) \qquad (\mathbf{9})$$

$$C = \frac{\pi\varepsilon_0\varepsilon_r}{cosh^{-1}\left(\frac{d}{2r}\right)} \quad (F/m) \qquad (10)$$

$$G = 2\pi f C \, tan\left(\frac{1}{\sqrt{\pi f \mu_0 \mu_r \sigma)}}\right) \quad (S/m) \qquad (11)$$

Where, $\mathbf{r = 0.8mm}$ is the radius of the conductors, $\mathbf{d = 3.2mm}$ is the distance between the conductors, σ is the electric conductivity of the conductors $\sigma = 5.5758.10^7$, μ is the magnetic permeabilit ($\mu = \mu_0\mu_r$; $\mu_0 = 4\pi \cdot 10^{-7}$ H/m ; $\mu_r = 1$) , ε is the dielectric constant ($\varepsilon = \varepsilon_0\varepsilon_r$; $\varepsilon_0 = 8.8419 \times 10^{-12}$ F/m).

3 Application of Electric Network

In the simulations, two topologies were considered: first, a small topology with one branch, second, a topology with many branches.

3.1 Influence of Line length

In this part, we are going to see the influence of line length on response of the PLC channel, the configuration under study is given in **figure 3** with l=5m, $Z_S=Z_L=Z_C$, Z_l=50Ω and line length L the line length Transmitter receiver was varied as 20m, 50m, 100 m and 200m.

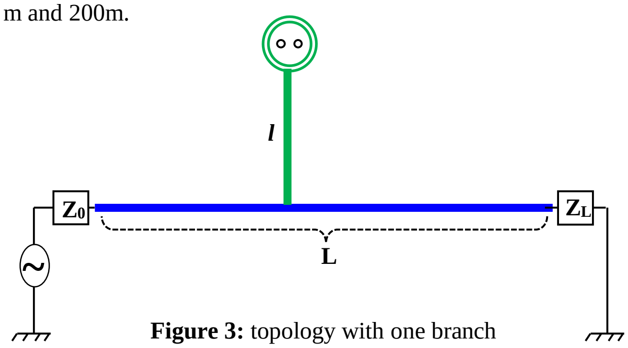

Figure 3: topology with one branch

The results obtained in fig. 4 illustrate a influence of line length on frequency response of the transfer function of the power line channel. Fig.4 show clearly the difference between the curves, such as we can see when increasing the length of the line when the attenuation was important.

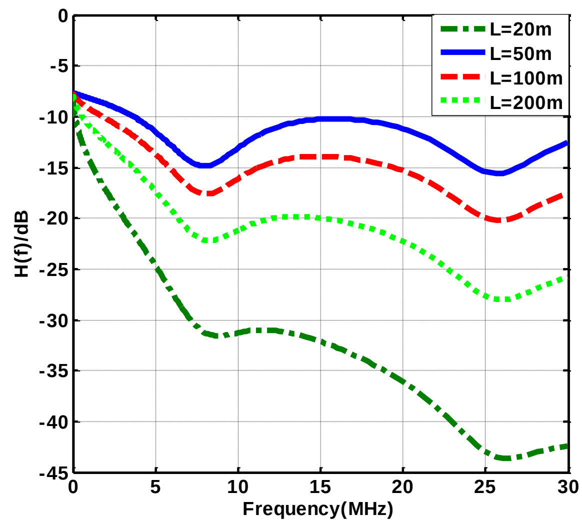

Figure 4: Simulation results for topology with one branch terminated by Z_l=50Ω.

The position of notches in the transfer function of medium voltage channel, also not depend on length from transmitter to receiver.

3.2 Influence of type's charge

We now consider the same configuration as given in Figure 3 with l=5m and the length from transmitter to receiver is L=20m.

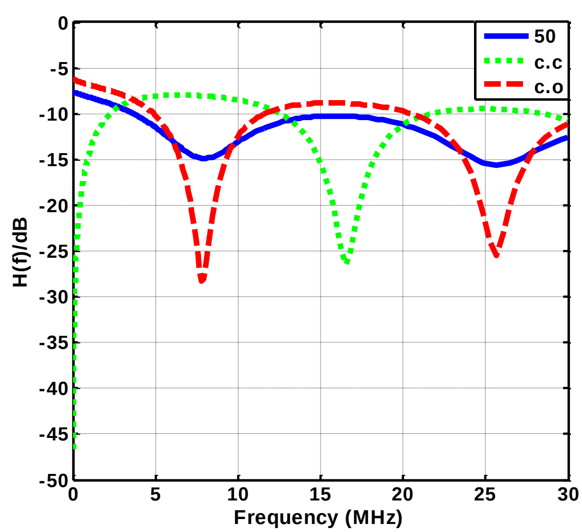

Figure 5: Simulation results of amplitude response: CO, CC, 50Ω.

We note Fig.5 that the transfer function of the terminated line on open-circuit C.O sockets experiences significant fading as low as -30dB. The simulation of a short-circuit CC generates strong disturbances on the transfer function, which can reach -50dB. Using a resistor of 50Ω to fit the line helps limit these fluctuations and maintain a more stable level -15dB.

3.3 Influence of branches and its length

In this case, we consider the configuration of Figure 3 with the load connected to the end of the branch is equal to 50Ω and L=20m.

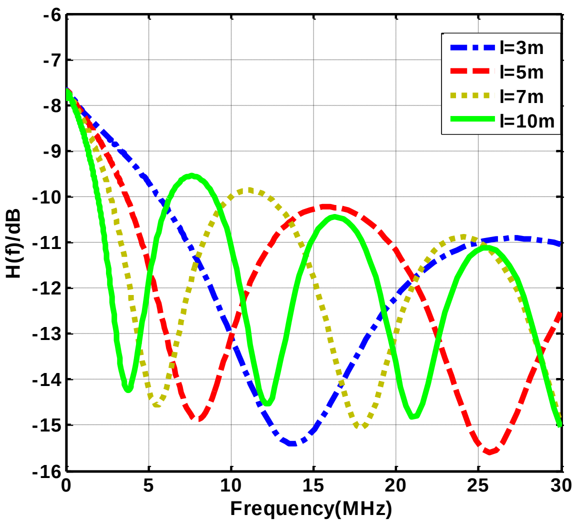

Figure 6: Effect of the branch length

The results obtained in fig.6 show clearly that the intensity of the levels of the fading phenomena does not depend on the length of the branch. Also show the corresponding frequency responses for various branch line lengths. It is observed that in all cases the peaks of frequency responses for various branches was not either attenuating with frequencies or branch length similar to the earlier case. Whereas, the position of the peaks and notches is case dependent unlike the previous case.

3.4 Influence of position branch

We consider the power line channel with distributed branches as shown in Figure3 with l=5m and Z_l=50.

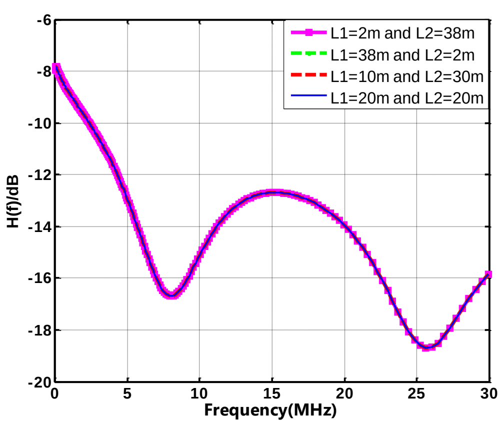

Figure 7: the effect of the position of the branch

We note that the distance between transmitter and receiver was kept constant at 40m.

We can thus observe a very good agreement between all the results of Fig.7. Consequently, the position of the branch on the principal line has no influence on the transfer function.

3.5 Influence of number of branches

We consider the power line channel as the number of branches was varied in the link between transmitter and receiver. We note that the distance between transmitter and receiver was kept constant at L=100m, while all branches were 5m long. The impedances connected to the ends of the branches are identical and is equal to 50Ω. The number of branches was varied as 1, 2, 3 and 4.

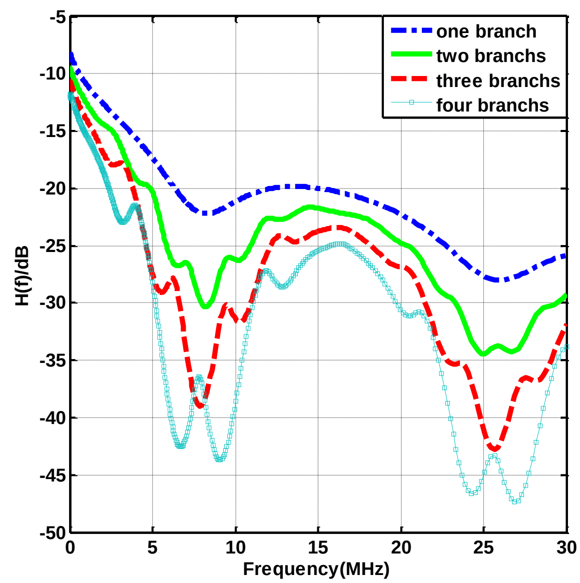

Figure 8: simulation results the effect of number of branches

The results obtained in fig.8 are similar and do not show any frequency shift and there is only the difference of the intensity of level between the curves of the figure, this difference exceeds 16dB when passing from a case of only one branch to that of two branches. This difference becomes greater in the case of structure (c). As a consequence, the influence of the branch on the structure of the line is lowered the levels of fading of the transfer function.

4 Conclusion

In this work, we were interested in modeling the transfer function of a electrical network by the approach of Transmission Line method. After that, we studied the impact of loads condition, the geometrical parameters of the line such as the length of the main line, the length of the branch, the position of the branch and the number of branch.

From simulations, we notice that the notches and pulse distortion in PLC channel do not depend on the line. However, the position of notches in channel transfer function depends on length of the branched. Moreover, the increase in branched line length tends to limit the available bandwidth in the medium voltage channel.

Finley we shown that, as the number of distributed branches increases the amplitude of notched points tends to increase making PLC channel a harsh environment for signal transmission.

Our future work aims to model the MIMO PLC channel for being used in MIMO-OFDM system.

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