전력선 통신에 기반한 홈네트워크의 채널 모델링

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Channel Modeling in Home Network based on Power Line Communication

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Abstract

이 논문은 홈네트워크에 있어서 전력선 통신의 채널 모델을 제안하였다. 전력선 통신의 특성은 노이즈, 감쇄현상, 위상변이를 고려해야만 한다. 본 연구에서는 노이즈 및 감쇄현상을 고려한 각각의 모델을 제시하였고 주파수 특성의 시뮬레이션을 통하여 모델의 유용성을 입증하였다.

I. Introduction

Home environment contains a number of complex electronic products and electrical systems. The major problem of home system is that they don't communicate with each other and don't share a common interface and information. To be successful in the home network, it must meet the several requirements: the network plug and play, the self-configuration, assignment for home appliance, the low cost cable and the energy management. The low cost wiring and energy management is hot issue in home network.

The realization of easy-to-use, low-cost network system are important factors for the implementing home network.

By these reasons, PLC(power line communication) have been developed recently[1-3].

PLC has the advantage of being an independent communications network where existing cable infrastructure can be used for dual purposes. The geographic coverage of the low-voltage system is usually very wide where human habitation exists, and the access to the network can be simple. On the other hand, power lines represent a particularly difficult communications environment. Noise levels may be excessive. The cable attenuation at frequency of interest to communication is usually very large. So repeater may be needed to compensate for cable losses, and to bridge over distribution transformers. Standing waves on line cables may lead to mulls in the frequency response. Electro-magnetic compatibility problems arise when interfacing electronic circuits with electrical power lines.

The previous study in power line pointed to high-voltage or middle-voltage power supply network. The characteristic in high-voltage is determined by long distance between power supply station to power distribution station[4-6].

But in home environment, noise, impedance, attenuation, and phase is determined by the response of home appliances. The attenuation model in low voltage is presented in high speed data transmission[7].

But noise model is almost skipped. And a channel model for the residential power circuit as a digital communication medium only is presented by the list to the measurement results of noise, impedance, attenuation, phase in the average value. The research also bring the focus to power line noise. Noise characteristics is investigated in respect to home appliances. In general, noise is considered as four components: background noise, impulse noise, synchronous noise, continuous noise[8-9].

But almost research investigated the point of the overall channel, not the noise source, home appliances.

The main purpose of this paper is focused on modeling and analysis of power line channel in home environment. New noise and attenuation model is proposed. For this model, the characteristics of power line channel is investigated. New model is simulated and discussed in frequency domain.

II. Power Line Channel Model

2.1 Noise Model

This paper follows the distinction of the four noise component, usually present in the power distribution network. First, the background noise is presented. Second, the random impulse noise is presented. Third, noise with synchronous frequency to 60[Hz] and its functions. Last, continuous noise is presented. Background noise has a smooth spectrum. The most important source of noise with a smooth spectrum is universal motors, i.e. small motors with serial windings.

Random impulse noise can be caused by lights and load switching in the network(capacitor bank, thermostat, refrigerator, air conditioner) with every impulse affecting a large frequency band. The pulse amplitude, width and the width gives the pulse energy.

Frequencies synchronous to the power line base frequency are generated mostly by light dimmers. Silicon controlled rectifiers triggered by power voltage cause a very short break in current flow. The length of the break determines the intensity of light.

As switching is synchronous to the power frequency a series of harmonics with various amplitude is generated. The setting of the dimmer and the characteristics of the lamp (bulb) dictate which harmonics carry most power. Usually, harmonics are small compared to the fundamental frequency, but due to communication signal can be far below their level. All switching devices operating on a similar principle ten to produce noise spikes synchronous to 60[Hz].

Figure 1 shows attenuation and noise measurement results gained at an earth cable connection with a length of 300[m]. It can be seen that attenuation generally increases with frequency. Such low-pass characteristic has been observed for all earth cable connections, and therefore should be regarded as one of the major properties of distribution grids at least in the frequency range above 500[kHz].

Furthermore some periodic fluctuations can be discerned in Figure 1.

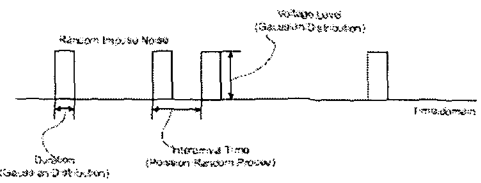

Figure 3. The model of impulse noise

2.2 Attenuation Model

The impulse response $h_E(t)$ may be written as:

$$h_E(t)=\sum_{i=1}^{N}k_i\delta(t-\tau_i) \quad (1)$$

where the coefficients τ_i denote the echo delays and the factors k_i stand for the echo attenuation respectively. From (1) the transfer function

$$H_E(f)=\sum_{i=1}^{N}k_i e^{-j2\pi f\tau_i} \quad (2)$$

can be calculated. Under real world conditions, however, the coefficients k_i are not only length, but also frequency dependent. After a series of different approaches, the following expression was found as a suitable description:

$$k(f,l_i)=a_i e^{-\alpha(f)e^{-\alpha(f)l_i}} \quad (3)$$

where l_i is the cable length and a_i denotes a specific factor regarding network topology details, such as number, length and termination of branches corresponding to the i^th echo path. The coefficient $\alpha(f)$ will need further explanation, given below. With (2) and (3), we finally have the complete transfer function

$$H_E(f)=\sum_{i=1}^{N}a_i e^{-\alpha(f)e^{-\alpha(f)l_i}}e^{-j2\pi f\tau_i} \quad (4)$$

Again, after a series of trials, it was found that in a first step the frequency dependent attenuation coefficient $\alpha(f)$ can be written as

$$\alpha(f)=\alpha_R(f)+\alpha_G(f)=\frac{R'}{2Z_L}+\frac{G'Z_L}{2}\approx v_1\sqrt{f}+v_2\sqrt{f} \quad (5)$$

Here $\alpha_R(f)$ describes the impact of the skin effect and in $\alpha_G(f)$ the dielectric losses within the insulation material are concentrated. The quantities R', G', Z' in equation (5) can be immediately calculated from geometrical cable analysis. A closer look reveals that $\alpha(f)$ contains a portion growing directly proportional with the frequency f and another growing according to the square root of f. Furthermore, it could be verified, that the coefficients v_1, v_2 are generally constant for a cable status and home environment. These significantly simplify set-up and handling of the proposed echo model in practical applications.

2.3 Simulation

In this paper, the proposed model of power line channel in Figure 2 is simulated. Figure 3 shows the measurement of power line channel in

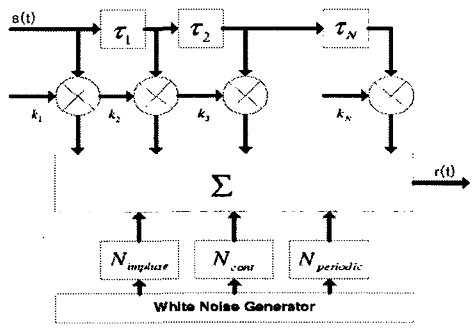

Figure 2. Proposed model of power line channel

frequency domain from 100kHz to 300kHz. And Figure 4 shows the simulation of power line channel in the same frequency domain. It is expressed as the sum of attenuated signal, background noise, impulse noise, synchronous noise, continuous noise. Overall response is very similar between the measured result and the simulated result. As the result of 100 iteration, the average value of attenuation is -23.5dB between 100kHz and 300kHz and its standard derivation is 4.27.

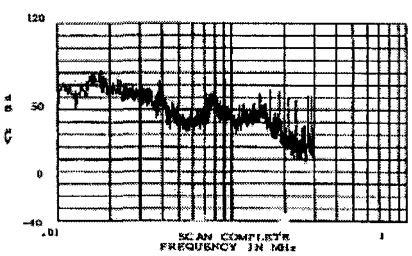

Figure 3. The signal response in power line channel

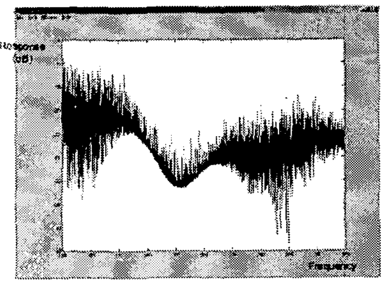

Figure 4. The simulation result

III. Conclusion

In this paper, a new model of the power line channel is proposed. The proposed model can be the base work to adapt power line communication to the home appliances and use power line communication in home environment.

The proposed model can be classified as attenuation model and noise model.

The proposed attenuation model is echo-based model. It can be expressed as the sum of component that home appliance generates. This model is in proportional to frequency. In the simulation result, frequency response by attenuation is -20dB in home network.

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