Modeling of High-Frequency Low Voltage Power Line Carrier Communication Channel

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***Abstract*—Low-voltage power line channel characteristics are designed for low voltage power line carrier communication system foundation. The paper used to design and develop a system for measuring the electrical characteristics of the low voltage power line communication network used to do high, including the noise characteristics of the input impedance characteristics, signal attenuation characteristics and systems, etc., a lot of experimental research. On this basis, the establishment of a low-voltage power grid will be used as a high-frequency carrier communication channel model. The model provides a practical and effective platform for the research and design of low voltage power line carrier communication system network has laid a good foundation.**

Keywords-Channel capacity; channel modeling; Group delay; Power-line communication (PLC)

I. INTRODUCTION

Due to the low voltage power line as a communication medium has extensive applications (across households), solid (and distribution network in one) and economy (no special channel), etc., as early as the 1970s and 1980s 2O once attention of researchers. In recent years, with the rapid development of increasing user demand for a variety of communications and related technologies, low-voltage power line carrier communication is becoming a hot research workers in science and technology at home and abroad. However, the low-voltage power grid as a matter of high-frequency carrier wave communication channel to use, you first need to face is to understand the complexity of the electrical characteristics of the channel, this feature compared to communicate with dedicated communication channels have almost completely different electrical characteristics. In addition, low-voltage power network with millions of households connected to the characteristics of a variety of electrical equipment produced by complex noise propagation in the power line will be different degrees of interference carrier signal transmission channel. Therefore, carrier communication channel itself is the basis of the electrical characteristics of low voltage power line carrier communication studies.

Low-voltage power line channel characteristic mainly includes the following three aspects: impedance : 1,channel input characteristic signal access points; 2, signal in the channel transmission, due to impedance mismatches and signal reflections node generated by the refraction phenomena transmission induced attenuation and phase shift characteristics; 3, noise characteristics caused by a variety of electrical equipment.

Abroad in this regard has been done more research work, mainly focused on the measurement of various frequencies within the range of the channel characteristics, there are also reports the results of the corresponding l1]. There are also at low frequencies (≤500 kHz) some interesting research on the electrical characteristics of the distribution network carried out.

This paper studies within the frequency range of 100 kHz-3 MHz with the electrical characteristics of the grid. Use test device developed by a large number of experiments carried out on the basis of these experimental results, the establishment of a 500 kHz-3 MHz frequency band used low-voltage distribution network carrier communication channel model.

Low voltage distribution network is very complex geometries, different lines with different wire or cable, so the big difference between them, if not impossible, to describe a whole theoretically be also very difficult, it requires technical collaborative research. A theoretical study of the long-term goal is to describe the characteristics of each part of the network, which helps us to understand the characteristics of a gradual deepening of complex networks.

II. NOISE MEASUREMENT METHOD

Power line carrier transmission as communication signals, each element of the network connection lines to study the basic transport properties, for the analysis of power line channel characteristics is necessary. Low-voltage distribution network generally consists of overhead lines and cable. In the vast rural areas, distribution station to supply users generally use overhead lines; and in densely populated urban areas, the general cable. However, for the average family of indoor power lines usually BV. BV are generally three wire-bound in a conduit or walking bridge (trough) inside. This is to some extent like a cable. This chapter first based on some assumptions, analysis of a simple two-conductor transmission line model, a common cable, the transfer function is derived. Then according to the three-line structure of the cable from the "crosstalk" perspective derived a three-conductor transmission line model, and proved to symmetrical three-conductor cables can become the equivalent two-conductor cable, finally introduces indoor wiring grounding specifications and discussed it three conductor cable conductor of the cable is equivalent to two impact.

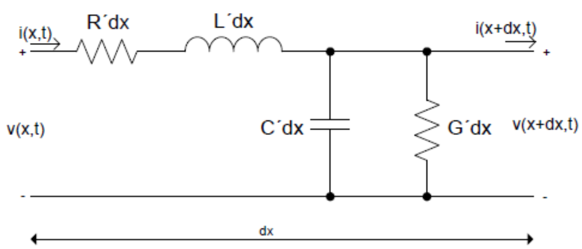

Figure 1. Elementary cell of a transmission line

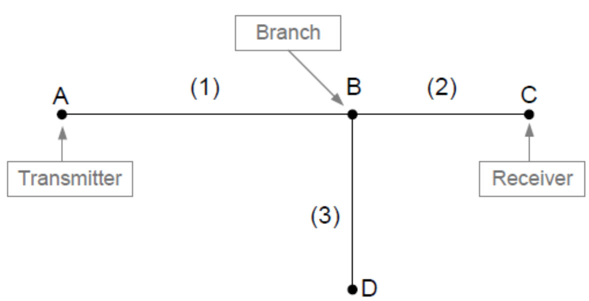

Figure 2. Topology of the sample network

III. PLC NETWORK STRUCTURE INSIDE THE CHAMBER

Today, there are many different pairs of conductors of the transmission line, coaxial cable, stripline and the like. They can use the distribution parameter model shown in Figure 2.4 the four configuration will be described. However, for each transmission line parameters have different values, depending on which requires the cable structure, wire timber, type, etc. of insulating material is calculated.

However, because the electromagnetic waves are in TEM mode propagation in the transmission line, the relationship between the parameters is the same. EM Mode refers to electric and magnetic fields are perpendicular to the direction of wave propagation in the cross section.

$$S_{21}=\frac{a(\omega)+b(\omega)Z_L}{c(\omega)+d(\omega)Z_L} \tag{1}$$

Noise low voltage distribution network is an important factor affecting the PLC reliable communications. But subject to the power line network designed from the beginning to consider restrictions, high-frequency signal transmission power lines are susceptible to external electromagnetic interference. Meanwhile, a variety of loads in a power grid access, will produce different characteristics of noise. Thus the need for different times, different frequencies, different scenarios make many measurements studies, statistical analysis of noise characteristics.

By 2.1 shows that the power line noise in accordance with the time / frequency characteristics and power spectral density characteristics can be divided into five. For the measurement of noise characteristics, the general coupler and oscilloscope / spectrum analyzer measurements. I.e., the noise signal by the coupling circuit is coupled to the oscilloscope, and the collected data is stored, and then import the data into a PC for analysis. The measuring principle is shown in Figure 2.6 below:

Low-voltage distribution network consists of a variety of different product types cables, transformers, consisting connection, while a variety of different types of electrical products access network terminal, the formation of different power line network topologies. Different power lines lay-line, such as overhead lines and underground cables, electrical transmission characteristics are also different. To sum up, the factors affecting the PLC network structure have : network location: Electricity demand in different regions differ, resulting in large differences in the structure of power line communication network. In the commercial and industrial clusters, the more general area of complex distribution networks, users with a high concentration. Distribution network structure of rural and urban differences also exist, but in all regions of the powerline communications needs are not the same;

Network Length: different supply network structures, transmission distance between the different position of the user and the transformer are not the same, resulting in a large difference in the same power line communication coverage area, this is particularly evident in rural areas; network design: low voltage distribution network architecture and the huge difference when degeneration, resulting in different network environments for each transmission. Meanwhile, the WAN connection (WAN) low-voltage distribution grid communications base position selection, it will lead to different users to communicate with the radio region relative position change, thereby changing the structure of the communication network.

Based on the above analysis can be found, there is a big difference between the low voltage distribution network structure. Impossible to specify a typical network structure to analyze the entire grid, but can be used for some typical station area analysis, the definition of some of the same characteristics of the stage area network architecture to provide a reference for the laboratory simulation of real-world scenarios.

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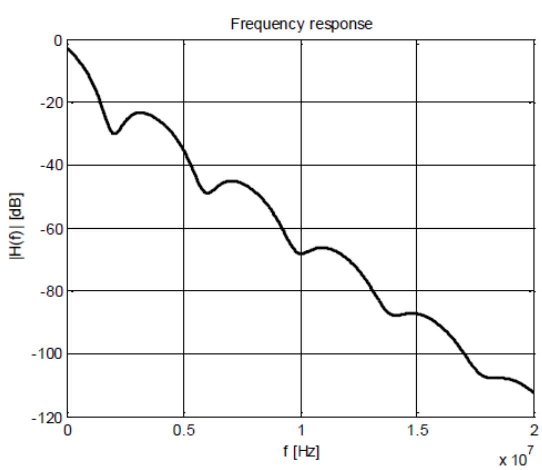

Figure 3. Simulation of the sample network

$$Attenuation(dB)_{f_i} = 20\times\lg\left(\frac{U_{r,f_i}}{U_{s,f_i}}\right) \tag{2}$$

$$A(f,d) = e^{-(a_0 + a_1 f^k)\cdot d} \tag{3}$$

$$\gamma=\alpha+j\beta=\sqrt{(R+j\omega L)(G+j\omega C)} \tag{4}$$

$$H(f)=\sum_{i=1}^{N}\rho_i \cdot e^{-j2\pi f\tau_i} \tag{5}$$

$$\boldsymbol{CM}_{m,m} = \begin{array}{c} \\ t_1 \\ \vdots \\ t_h \\ b_1 \\ \vdots \\ b_k \end{array} \begin{array}{c} \begin{array}{cccccc} t_1 & \cdots & t_h & b_1 & \cdots & b_k \end{array} \\ \begin{pmatrix} 0 & \cdots & 0 & c_{1,h+1} & \cdots & c_{1m} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & c_{h,h+1} & \cdots & c_{hm} \\ c_{h+1,1} & \cdots & c_{h+1,h} & c_{h+1,h+1} & \cdots & c_{h+1,m} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ c_{m1} & \cdots & c_{mh} & c_{m,h+1} & \cdots & c_{mm} \end{pmatrix} \end{array} \tag{6}$$

Connectivity matrix, the number of endpoints for the branch number of nodes is, the transfer order of the matrix. Order matrix values represent any node connectivity between states, when the value is 1, indicating that no other nodes relay nodes that can direct correspondence between the rows and columns. When the value is 0, the corresponding node can not communicate directly. By assumption we can see a direct link between any endpoint is not only connected to the neighboring branch node, so the matrix is zero matrix endpoints. Meanwhile, the same end-to-branch and branch node to node connectivity consistent port, so the matrix is a symmetric matrix, the matrix of end-to-value branch node are:

$$\boldsymbol{CM}_{m,m} = \begin{pmatrix} \boldsymbol{0}_{h,h} & \boldsymbol{CT}_{h,k} \\ \boldsymbol{CT}_{k,h}^{T} & \boldsymbol{CB}_{k,k} \end{pmatrix} \tag{7}$$

$$\boldsymbol{CB}_{k,k} = \begin{pmatrix} 0 & c_{12} & \cdots & c_{1k} \\ c_{21} & 0 & \cdots & c_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ c_{k1} & c_{k2} & \cdots & 0 \end{pmatrix} \tag{8}$$

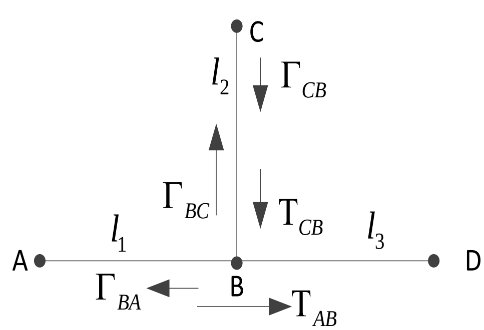

Figure 4. Transmissioin path of the sample network

$$A(f,d)=\exp((-a_0-a_1f^k)d) \qquad (9)$$

IV. Conclusion

This chapter begins from the spread spectrum technology, analyzes the feasibility of spread spectrum communication in power line carrier communication, and the principle of spread spectrum technology for analysis. Reference TD-SCDMA system basic midamble sequence, designed for the detection of power line broadband channel characteristic measurement signal. Using broadband reference signal combined vector signal generators, network analyzers, and other software and hardware equipment, power line broadband channel sounding build and validate semi-physical simulation platform, as in the actual distribution network environment, the power line broadband channel characteristic measuring the accumulation of experience .

The use of semi-physical simulation platform for school laboratory and classroom building scene a lot of field measurements, analysis of power line channel transmission characteristics of the different environments, and features a three-dimensional graphic display of variable power line channel under different scenarios. At the same time in order to improve the efficiency of the data analysis, the use of MATLAB simulation software design based on off-line data analysis software GUI interface. It receiving end signal processing module integrated into the GUI interface, to implement graphical data analysis and processing, and at the same time from multiple dimensions of the channel parameters display.

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