

# Ultra-Wideband Communication Transmission Mechanism Based on Power Line Carrier

Ran Li<sup>1,\*</sup>, Fanbo Meng<sup>2</sup>, Lu Yi<sup>1</sup>, Dongdong Wang<sup>1</sup>, Fan Wu<sup>1</sup>, Taiyi Fu<sup>1</sup> and Huadong Yu<sup>3</sup>

<sup>1</sup>Shenyang Power Supply Co., Ltd., Liaoning Provincial Electric Power Co., Ltd., Shenyang, Liaoning, China

<sup>2</sup>State Grid Liaoning Electric Power Co., Ltd., Shenyang, Liaoning, China

<sup>3</sup>DaJan Holding Group Electric Power Science & Technology Co., Ltd, China

\*Corresponding author

**Abstract**—This paper introduces the development and advantages of power line communication, studies and analyzes the characteristics of low-voltage power line channel and its model, and studies the system composition and principle of surface wave. A power line model was designed to realize broadband power line carrier communication.

**Keywords**—power line; carrier communication; surface wave; ultra-wideband

## I. BACKGROUND

With the gradual maturity of low-voltage broadband carrier communication technology, the promulgation of interconnection standards, the introduction of chips, modules and devices in line with the interconnection specifications, the low-voltage power line broadband communication technology has entered a stage of vigorous development. The development trend of power line carrier communication extends from the low-voltage side application to the medium-voltage side. The data communication on the medium-voltage side power line is slow due to the complex network structure and large attenuation. Therefore, it is limited to low-speed data transmission and limited high-rate testing, and there is still a long way to go from practical applications. From the current Mbps-class communication rate to a higher rate, from a single power service application to an integrated information service, especially the use of power line high, medium and low voltage distribution network to achieve deep integration with future 5G communication[1].

## II. DEVELOPMENT STATUS

Power line carrier communication technology refers to a communication method that uses power lines as a medium for voice or data transmission. From around 2005, many international research institutes, telecommunications companies and business units began to research and deploy advanced PLC technology suitable for smart grid applications, and led the research on PLC technology for smart grid applications. China's narrow-band power line carrier communication used foreign chips before and after 1998. Later, domestic manufacturers launched small-band PLC chips with independent intellectual property rights.

From the application of PLC technology in the power industry, there are still some problems, mainly in the following: medium voltage PLC still mainly adopts narrowband technology, the communication rate is low, the networking capacity is not strong, and it is difficult to meet more real-time communication of smart grid. And control, as well as application requirements for future network communication protocols. The medium voltage line coupler has a large installation workload and is inconvenient to maintain. Some areas require power failure installation and maintenance [2]. Low-voltage PLCs are gradually evolving toward broadband, but they still face problems such as large signal attenuation, limited single-hop communication distance, and sharing of some frequency bands with other fields.

## III. POWER LINE MODEL

In this paper, the power line waveguide is simplified, and the power line model is simplified. Next, the transmission characteristics of the simplified model are studied, then the power line waveguide discontinuous research is carried out, and then the excitation and reception of the power line surface wave are studied.

### A. Waveguide Frame Model

The research process uses a combination of analytical methods and numerical methods. For the problem of simple boundary, the project uses analytical methods to obtain a general solution, and then uses numerical methods to further optimize the results. Such problems include the propagation constant, dispersion characteristics, characteristic impedance, and field mode distribution of the waveguide. For the discontinuity, excitation structure and receiving structure of the waveguide, the project uses the approximate analytical analysis method to assist the numerical calculation method. Study the design of different incentive and receiving schemes, the main method is numerical calculation. In addition, the results of the approximate analytical solution are used to accelerate convergence. The power line waveguide frame diagram is shown in Figure 1.

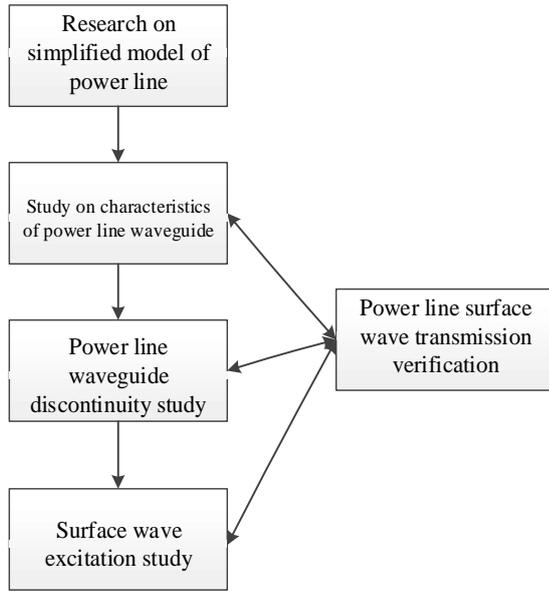


FIGURE I. POWER LINE WAVEGUIDE FRAME DIAGRAM

In order to verify the correctness of the theoretical research, the project will conduct multiple iterative experiments. The verification system is shown in Figure 2.

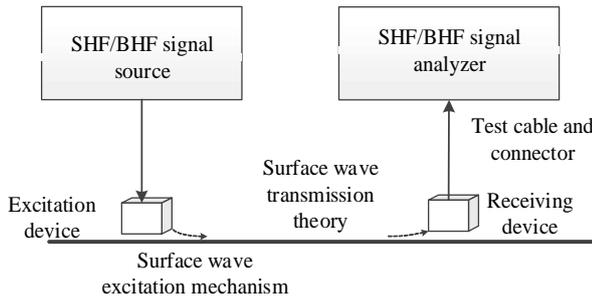


FIGURE II. SCHEMATIC DIAGRAM OF SURFACE WAVE BROADBAND COMMUNICATION VERIFICATION SYSTEM

As shown in Fig. 2, the verification test system of the surface wave broadband communication project is divided into four parts: surface wave transmission theory, surface wave excitation mechanism, surface wave receiving mechanism, and millimeter wave feeding mechanism. Because these parts have some dependencies on each other, when studying one item, it is necessary to adopt another part of the simplified model. For

example, the surface wave excitation mechanism requires the use of a feed structure.

### B. Basic Transmission Characteristics of Power Lines

The power line transmission line is a guided wave system composed of a signal line and its surrounding medium, and is the basis of the surface wave transmission system[3].

The transverse cross-sectional dimension of the transmission line conductor and its surrounding medium remains constant along the axis of the transmission line. This type of transmission line structure is called a uniform transmission line. Uniform transmission line has only one characteristic impedance. The electrical parameters of the unit length on the line are uniformly distributed in all spatial positions of the transmission line, and the length of the transmission line has a direct influence on the characteristics of the signal.

When the transverse section dimension of the transmission line varies along the transmission line axis direction Z, the transmission line of such a structure is referred to as a non-uniform transmission line. The non-uniform transmission line has no characteristic impedance and only instantaneous impedance, and the instantaneous impedance of each point on the line is different[4]. The non-uniformity of the non-uniform transmission line mainly indicates that the parasitic parameters of the points on the line change with the change of the position, thereby destroying the continuity and symmetry of the electromagnetic waves propagated by the transmission line.

## IV. STUDY ON EXCITATION MECHANISM AND STRUCTURE OF SURFACE WAVES OF POWER LINE WIRES

### A. Basic research ideas of surface wave coupling

The surface wave excitation mechanism is studied. The solution is that the energy of the millimeter wave needs to be transmitted efficiently. The first step is to use a horn antenna to effectively radiate millimeter wave energy for testing and verification. Then, based on the test results, it is studied how to realize a highly efficient coupling device, and realizes that electromagnetic energy is concentrated on the surface of the wire and transmitted along the wire. According to the analysis results, the implementation is as shown in Figure 3:

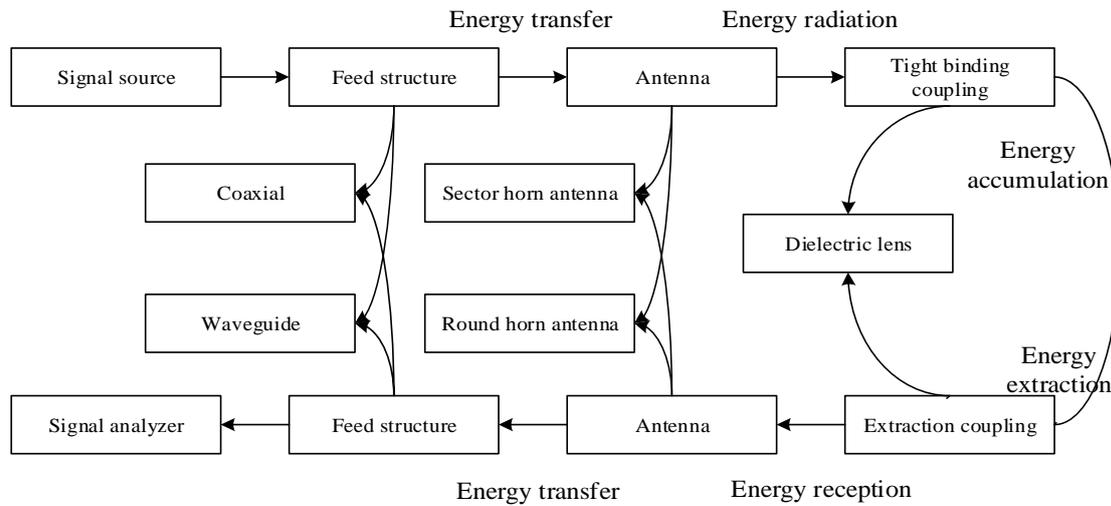


FIGURE III. SURFACE WAVE EXCITATION MECHANISM SCHEME DIAGRAM

The coupling mechanism study should be combined with the test system. The output and input ports of the upper and lower frequency converters are selected as rectangular waveguides[5]. A rectangular waveguide is selected as the feeding structure, a sector horn antenna is selected as the radiation antenna, and the dielectric lens is selected as the excitation and coupling device.

**B. Coupling Device**

The coupling device is divided into a tight binding coupling device and a decoupling coupling device. According to the electromagnetic restraint theory, if a binding effect is to be formed in the corresponding region, it is necessary to form a reactive boundary condition in this region. There are two ways: the boundary between two different dielectric constant media, the conductor boundary. The electromagnetic energy is bound to the power line, and the power line has a dielectric layer, which belongs to the case where the conductor boundary and the medium boundary coexist.

The primary purpose of the coupling device is to concentrate the electromagnetic energy on the surface of the 10 KV conductor so that it propagates in a lateral direction parallel to the conductor surface without entering the conductor for longitudinal power line carrier transmission, thereby avoiding transmission attenuation. The core is to study high-efficiency antenna radiation and signal excitation and coupling technology under the premise of selecting a suitable waveguide as the feed structure[6].

**V. STUDY ON THE RECEIVING MECHANISM AND STRUCTURE OF SURFACE WAVE OF POWER LINE CONDUCTOR**

**A. Composition of Power Line Surface Wave Communication System**

Under certain conditions, surface electromagnetic waves are formed on the surface between two different media, and the waves exhibit attenuation characteristics in the medium

perpendicular to the interface and are transmitted along the interface. The surface wave waveguide includes: a two-dimensional two-layer medium interface, a two-dimensional metal and air interface, a two-dimensional corrugated pleated surface, a circular dielectric rod, a metal grid covering a round metal rod, and a dielectric covering metal.

The power line surface wave communication system mainly includes a transmission line in addition to a general information processing and digital modulation and demodulation portion. The transmission line is composed of a power line conductor and an insulating layer, and the coupled waveguide has a rectangular waveguide, a circular waveguide, a coaxial line, and the like. A system in which a metal wire located in a medium is used as a transmission mode is a surface electromagnetic wave waveguide.

**B. Waveguide Coupling and Receiving Technology**

- Circular + fan hybrid coupling

At present, the power line surface wave coupling technology, such as the coupling technology of AT&T in the United States, uses a circular + fan-shaped horn to couple the surface electromagnetic waves, which is huge in volume, and needs to pass the exposed power line circular metal wire along the center line through the horn.

- Rectangular aperture coupling

Rectangular aperture coupling is basically applied to planar surface wave waveguides. One side of the rectangular waveguide needs to be close to the planar surface wave waveguide, and the field at the aperture directly extends to the surface wave waveguide plane, which is not suitable for the characteristics of the power-oriented cylindrical type[7].

The surface wave coupling and receiving mechanism of power line conductors is studied. The surface wave coupling and receiving mechanism is studied. A new surface wave guiding mechanism is designed to realize the matching between

the electromagnetic wave main mode and the power line conductor and medium, so that the electromagnetic field energy is injected into the conductor as much as possible.

- A Service Flow Modeling Method for Power Line Ultra-Wideband Communication Transmission

With the demand for power network management and the emergence of new applications, power line ultra-wideband has been applied and deployed into power communication networks. End-to-end traffic behavior in communication networks embodies path-level and network-level features in the network. This can be used to describe network status and nature, such as path load, throughput, network utilization, and more. By performing a modeling process, these methods can better predict and estimate end-to-end traffic. This paper proposes a more convenient traffic flow modeling method for power line ultra-wideband communication transmission, including the following steps as shown in Figure 4.

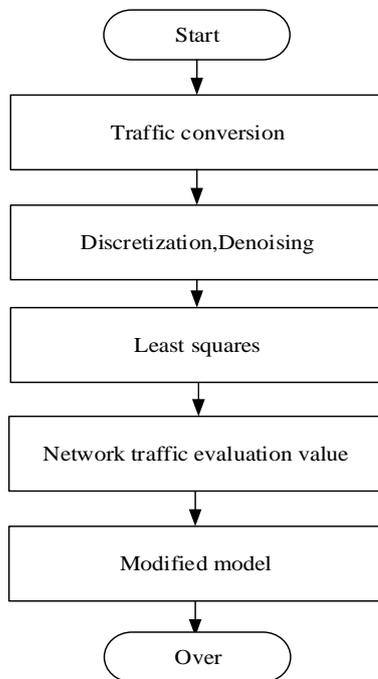


FIGURE IV. BUSINESS TRAFFIC MODELING METHOD

This paper presents a traffic flow modeling method based on Walsh transform for traffic flow modeling of ultra-wideband communication[8]. The project uses real data from the Abilene backbone network in the United States to verify ultra-wideband for power lines. By comparing the algorithm of WTMA with PCA, WABR and HMPA network flow model, we can find that the business flow modeling method proposed in this project can effectively grasp the dynamic change of end-to-end network traffic for different time slots, the real end. End-to-end network traffic exhibits significant time-varying nature while also capturing the trend of end-to-end network traffic.

## VI. SUMMARY AND OUTLOOK

The project system carried out research on the electromagnetic surface wave transmission characteristics of the power line, and gave the physical model of the dielectric coated 10KV wire. The basic theory of high-frequency signal propagation of power lines as transmission lines is expounded, and the transmission characteristics of surface waves at discontinuous lines of power lines are analyzed. The coupling and receiving mechanism of the surface wave of the power line conductor and the surface wave coupling and receiving mechanism are studied. The main mode of the electromagnetic wave is matched with the power line conductor and the medium.

The results of this paper are based on a simple experimental device. The transmission of real power lines needs to further improve the test configuration, excitation and coupling devices. Further, the signal transmission and reception performance of ultra-wideband needs further testing. The coupling device of the transmitting end and the receiving end is very important, and relates to antenna technology, wave aggregation technology, medium construction technology and the like. The next implementation direction can be determined by the use of dielectric lens method to achieve electromagnetic wave aggregation and extraction, long-distance low-loss surface wave communication system design.

## REFERENCES

- [1] Ali Hadi Abdulwahid, Diyah K. Shary. Improve Protection Concept of Transmission Line Based on Power Lines Carrier for microgrid[J]. IOP Conference Series: Materials Science and Engineering, 2019, 518(4).
- [2] Comanche Electric Migrates from Power Line Carrier System to AMI[J]. Transmission & Distribution World, 2018.
- [3] Reza Jalilzadeh Hamidi, Hanif Livani. Adaptive single-phase auto-reclosing method using power line carrier signals[J]. International Journal of Electrical Power and Energy Systems, 2018, 96.
- [4] Wang Yi, Deng Ziqiao, Wen Hui'an, Hou Xingzhe, Li Songqiang, Sun Hongliang, Zheng Ke. Research on multi-node based low-voltage broadband power line channel modeling method[J]. Power System Protection and Control, 2018, 46(03): 18-25. (in Chinese)
- [5] Chien-Hung Yeh, Yao-Jen Chang, Chi-Wai Chow, Wen-Piao Lin. Utilizing polarization-multiplexing for free space optical communication transmission with security operation[J]. Optical Fiber Technology, 2019, 52.
- [6] Longsheng Wang, Yuanyuan Guo, Daming Wang, Yuncai Wang, Anbang Wang. Experiment on 10-Gb/s message transmission using an all-optical chaotic secure communication system[J]. Optics Communications, 2019, 453.
- [7] Dhatchayeny Durai Rajan, Chung Yeon Ho. Optical extra-body communication using smartphone cameras for human vital sign transmission.[J]. Applied optics, 2019, 58(15).
- [8] Jozef Tkocz, Steven Dixon. Electromagnetic acoustic transducer optimisation for surface wave applications[J]. NDT and E International, 2019, 107.