Research on micro power wireless communication system based on OFDM technology

Yan Long[a,b*], Yongli Chen[a,b], Zhihua Bai[a,b], Xiaoqing Zhao[a,b], Ziqi Dong[c]
[a] State Grid Key Laboratory of Power Industrial Chip Design and Analysis Technology, Beijing Smart-Chip Microelectronics Technology Co., Ltd., Beijing 100192, China; [b] Beijing Engineering Research Center of High-Reliability IC with Power Industrial Grade, Beijing Smart-Chip Microelectronics Technology Co., Ltd., Beijing 100192, China; [c] State Grid Information & Telecommunication Branch, Beijing 100192, China

ABSTRACT

The mainstream modulation technology of micro power wireless communication chip is (G) FSK ((Gauss) Frequency Shift Keying), but this technology has the defects of wide bandwidth occupation, low bandwidth utilization and low sensitivity. To solve this problem, improve the performance and frequency band utilization of micro power wireless communication system, and realize the high reliability and real-time of communication, a micro power wireless communication system based on OFDM (Orthogonal Frequency Division Multiplexing) technology was proposed in this paper, which can effectively improve the reliability, real-time and receiving sensitivity of meter reading. The test results show that this method meets the functional and performance requirements of state grid interconnection.

Keywords: OFDM, micro power wireless communication, receiving sensitivity

1. INTRODUCTION

Micro power wireless communication is a kind of wireless communication. The technology uses 433MHz, 470 MHz-510 MHz, 2.4GHz and other frequency bands, and the coverage can reach hundreds of meters[1]. With the rapid development of social economy, the scale of electric power continues to expand, and the complexity of lines is increasing day by day. Compared with power line carrier communication, micro power wireless communication has the advantages of no wiring, high communication reliability, fast communication rate and stable network. It is widely used in power lines[2].

At present, the modulation technology used by the mainstream micro power wireless communication technology is mainly (G) FSK. However, this technology has the defects of wide occupied frequency band, low frequency band utilization and low sensitivity. A micro power wireless communication system using OFDM technology is proposed in this paper, which can effectively improve the reliability, real-time and receiving sensitivity of meter reading.

The organizational structure of this paper is as follows: a micro power wireless communication system using OFDM technology is proposed; in Section 2, the Micro power wireless communication technology are presented. Micro power wireless communication technology using OFDM is presented in Section 3. Section 4 presents the test steps and results. In addition, section 5 makes some conclusions.

2. MICRO POWER WIRELESS COMMUNICATION TECHNOLOGY

Wireless communication is the focus of current communication technology research, and its application in smart grid is becoming more and more extensive. Wireless communication is an important means to realize the power Internet of things. Spectrum resources are the basis and technical system is the key[3]. The micro power wireless communication system does not have the problem of spectrum authorization, and the technology is relatively mature. The communication indicators can basically meet the needs of intelligent power consumption. It can be used as a supplement to optical fiber, PLC and other communication methods in the intelligent power consumption network to expand the network coverage[4].

In the application of micro power wireless communication technology, the main technical problem is reflected in the

[*] longyan@qq.com

Third International Conference on Computer Science and Communication Technology (ICCSCT 2022)
edited by Yingfa Lu, Changbo Cheng, Proc. of SPIE Vol. 12506, 1250656
© 2022 SPIE · 0277-786X · doi: 10.1117/12.2662014

effectiveness of signal reception. To improve the effectiveness of signal reception, we must ensure the strength of the received signal[5].

3. MICRO POWER WIRELESS COMMUNICATION TECHNOLOGY BASED ON OFDM

Wireless communication technology is the main technology for the construction of power line communication network in China. At present, micro power wireless communication technology has been widely used by virtue of its flexible networking and simple system.

3.1 OFDM technology

OFDM (orthogonal frequency division multiplexing) is the simplest and most widely used multi carrier transmission scheme[6]. This technology can maximize the use of spectrum resources, greatly improve the data transmission rate, and it shows great advantages in anti symbol to symbol crosstalk and inter channel interference, so it has been widely concerned in the field of wireless communication.

The basic principle of OFDM is that the high-speed information data is encoded and distributed to N parallel orthogonal subcarriers. The modulation rate on each carrier is very low. The signal bandwidth on each carrier is smaller than the relevant bandwidth of the channel, which can be seen as flat fading, so that inter symbol crosstalk can be eliminated and channel equalization is relatively easier[7]. The difference between OFDM and general multi carrier transmission is that it allows the subcarrier spectrum to overlap partially. As long as the subcarriers are orthogonal to each other, the data signal can be separated from the aliased subcarriers. Because OFDM allows subcarrier spectrum aliasing, its spectral efficiency is greatly improved, so it is an efficient modulation method. The system model of OFDM is shown in Figure 1.

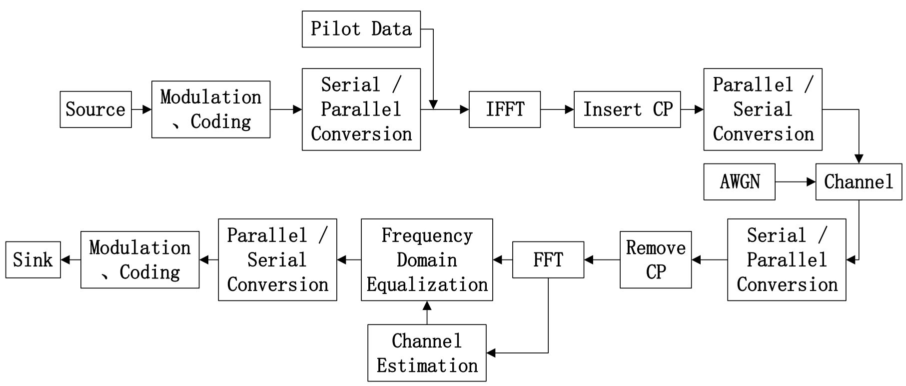

Figure 1. The system model of OFDM.

At the end of transmitting, the serial data is converted into n-channel parallel subchannel signals through serial parallel conversion, and then digitally modulated. A series of complex data streams can be obtained by means of phase shift keying (PSK) or quadrature amplitude modulation (QAM). The digital modulation mode adopted by each subcarrier channel can be different, which is determined according to the current condition of the subcarrier channel. Then, the complex number allocated on each subchannel is used to de modulate the carrier of each subchannel[8]. The OFDM symbol is obtained by the superposition of the modulated signal, which can be expressed as:

$$s(t) = \sum_{i=0}^{N-1} d_i \, rect(t - t_s - t/2)\exp\left(j2\pi f_i (t - t_s)\right), t_s \le t \le t_s + T \tag{1}$$

where, N is the number of subcarriers, T is the duration of OFDM symbols, d_i is the data symbols allocated to the ith channel, and is a rectangular function; $|t| \le T/2$; f_i is the carrier frequency of the ith subcarrier.

At the receiving end, demodulate the k-th subcarrier in the formula, and then integrate in T time period[9]:

$$\widehat{d_k} = \frac{1}{T}\int_{t_s}^{t_s+T} s(t)\cdot \exp\left(-j2\pi \frac{k}{T}(t - t_s)\right)dt$$

$$= \frac{1}{T}\sum_{i=0}^{N-1} d_i \exp\left(j2\pi \frac{i-k}{T}(t - t_s)\right)dt = d_k \tag{2}$$

It can be seen from the above formula that the desired symbol can be recovered by demodulating the *k*-th subcarrier, while for other subcarriers, the integration result is 0 because the frequency difference in the integration interval can produce integer multiple cycles. Each subchannel signal is separated from the OFDM signal, and then the complex signal is restored to the real signal through digital demodulation. After parallel serial conversion, it is restored to the received data at the receiving end[10]. It can be seen from the analysis of the n-channel modulation signal generated by the above subcarrier, and it is strictly required to synchronize the signal generated by each subcarrier. In this way, when n is large, the system is difficult to implement, which is not conducive to practical application. The modulation and demodulation of the baseband signal is used to replace sinusoidal generator and demodulator, which can significantly reduce the complexity of multi carrier system[11].

The data transmission rate of OFDM system is very high and can approach the limit of channel transmission rate, which is mainly determined by the frequency domain characteristics of OFDM. When the symbol is a rectangular pulse, the frequency band utilization is not high, while the spectrum of OFDM is approximately rectangular in general, and its sideband components become very small after overlapping each other. Therefore, the spectrum efficiency of OFDM signal can theoretically reach the limit of Shannon information theory[12]. OFDM system has strong anti pulse interference ability, because the demodulation of OFDM signal is integrated in a long symbol period, so that the influence of pulse noise can be dispersed. In addition, OFDM system can effectively overcome the influence of multipath propagation by dispersing information on many carriers, which greatly reduces the signal rate of each subcarrier and makes the symbol period longer than the multipath delay. OFDM allows 1/2 overlap of adjacent signal spectrum, which will inevitably cause inter symbol crosstalk. Measures such as cyclic prefix and time-domain equalization can be adopted to effectively reduce the impact of inter symbol crosstalk[13]. OFDM is also suitable for micro power wireless communication because of its strong ability to resist pulse interference and multipath effect.

3.2 Application of OFDM technology in micro power wireless communication

At the transmitting end, the system receives data from the data link layer. After a series of signal processing and transformation, the encoded data is processed by OFDM modulation, and the formed OFDM signal is sent to the analog front end and sent to the air. At the receiving end, the received signal is demodulated and decoded accordingly, and finally the analog signal is restored to the decoded data information and sent to the data link layer for subsequent protocol analysis.

Micro power wireless communication technology improves the receiving performance of the receiver and the transmission quality of data by using OFDM technology.

4. TEST STEPS AND RESULTS

4.1 Test items

Verify that the receiving sensitivity of the device under DUT meets the following values under the condition that the packet error rate is less than 10%. The reception sensitivity index corresponding to the combination of OFDM mode and MCS is shown in Table 1.

Table 1. Reception sensitivity corresponding to the combination of OFDM mode and MCS.

Test parameters	OFDM mode (dBm)
PSDU MCS0	-109
PSDU MCS1	-106
PSDU MCS2	-103
PSDU MCS3	-100
PSDU MCS4	-97
PSDU MCS5	-94
PSDU MCS6	-91

4.2 Test steps

The test steps are as follows:

(1) The equipment is connected and the DUT is initialized;

(2) The platform environment is initialized to ensure that the noise is turned off. The clock source provided by the transparent access device is used and the transparent device sends the fixed power (P). The default attenuation value of the program-controlled attenuator is set to 20dB;

(3) The software platform sends 20 test command frames on different carrier frequency bands, sends 3 rounds of cyclic transmission, and sets the target wireless working channel of DUT;

(4) The software platform sends 20 test command frames (OFDM mode/MCS1) to make the DUT enter the transparent transmission mode of RF physical layer;

(5) The software platform continuously sends 5 beacon frames for clock synchronization of the equipment to be tested, and the beacon interval is 1s (the equipment to be tested (CCO/STA) receives the beacon only for clock synchronization and does not send back);

(6) The software platform selects the test message in the following test parameter list, sends the test message to the transparent access device, saves the FC + PB content of the message (ACK only retains FC), and sends it 500 times (5 beacon frames are sent every 100 frames);

(7) The transparent forwarding device forwards the test message sent by the software platform to the PLC. After receiving the message, the DUT reports the data of the received message through the serial port (fc16 bytes + Pb block data of the load).

(8) After the software platform receives the content of FC + PB message, compared with the content saved before sending, if the received content of FC + PB is the same as the sent content, it is considered that the message DUT transmission is successful, and the number of successful communications is increased by 1. If the data of the previous and subsequent messages are inconsistent, the number of successful communications remains unchanged;

(9) The success rate is calculated. The test can be ended if the success rate is less than 90%. If the success rate is greater than 90%, the value of the program-controlled attenuator is increased. Steps (5)-(9) are repeated until the success rate is just less than 90%. The attenuation value of this MCS mode is recorded, and the reception sensitivity is equal to transmission power p-attenuation value of transparent equipment;

(10) The next mode is selected and Steps (3)-(6) are repeated (when switching from the current test channel to the next test channel, the wireless channels of DUT, transparent access unit and carrier listening unit need to be reset).

4.3 Test results

The sensitivity test results are shown in Table 2, in which the frequency of OFDM mode of micro power wireless communication system is set to 476 MHz.

Table 2. Performance test results.

Parameter	Standard value	Measured value of OFDM mode (dBm)	Test result
PSDU MCS0	-109	-112	Pass
PSDU MCS1	-106	-111	Pass
PSDU MCS2	-103	-108	Pass
PSDU MCS3	-100	-106	Pass
PSDU MCS4	-97	-102	Pass
PSDU MCS5	-94	-101	Pass
PSDU MCS6	-91	-96	Pass

4. CONCLUSION

This paper presents a wireless communication system using OFDM technology. Through the application of OFDM technology, the performance and frequency band utilization of micro power wireless communication system can be effectively improved. The test results show that this method meets the functional and performance requirements of national network interconnection, and improves the reliability, real-time and receiving sensitivity of meter reading.

REFERENCES

[1] Zhang, H. L., Tang, Y., Dou, J., et al., "Research on the micro-power wireless communication testing technique," Electrical Measurement & Instrumentation, 53(14), 96-100+117(2016).

[2] Tan, X. and Lu, J., "Application of micro power wireless communication technology in low voltage meter reading," Digital Technology and Application, (3)2, (2012).

[3] Huang, Z. L., "Research on Adaptability of micro power wireless communication technology in power line," China New Communications, 19(11), 1(2017).

[4] Yu, L. H., Zhao, X., Cao, M., et al., "Design on micro-power wireless communication network evaluation system," Yunan Electric Power, 45(06), 77-80(2017).

[5] Chen, S. Q., "Using micro power wireless communication technology to improve the operation efficiency of power lines," Port Economy, 89-91(2018).

[6] Huang, Y. T., "Research and application of multi meter reading based on micro power wireless," Modern Scientific Instruments, 5(10), 99-102(2019).

[7] Li, F., Wang, H. X., Tang, R. Y., et al., "Communication scheme and simulation study of irrigation and drainage meter based on micropower wireless communication technology," Hebei Electric Power, 37(06), 12-14(2018).

[8] Shi, Y. G. and Tian, H. T., "A method of Interconnection Network detection for wireless communication modules of metes," North China Electric Power, (6), (2014).

[9] Diet, A., Berland, C., Villegas, M., et al., "EER architecture specifications for OFDM transmitter using a class E amplifier," IEEE Microwave and Wireless Components Letters, 14(8), 389-391(2018).

[10] Izumi, S., "Communication device for receiving and transmitting OFDM signals in a wireless communication system," US US7633848 B2, (2018).

[11] Zaidi, A. A., Robert, B., Vicent, M. C., et al., OFDM numerology design for 5g new radio to support IoT, EMBB, and Mbsfn IEEE Communications Standards Magazine, 2(2), 78-83(2018).

[12] Yan, S., Yang, X., Wang, X., et al., "Predicting the power spectrum of amplified OFDM signals using higher-order intercept points," Chinese Journal of Electronics, 31(2), 213-219(2022).

[13] Marzban, M. F., Shafie, A. E., Chabaan, R., et al., "Securing OFDM-based wireless links using temporal artificial-noise injection," 2018 15th IEEE Annual Consumer Communications & Networking Conf. (CCNC), (2018).