High-Precision Time Transfer based on Power Line Communication

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***Summary*—Time transfer is widely used in several fields. Conventional time transfer links such as optical fiber and radio cannot work stably during military readiness or war conditions. Power line communication (PLC) is safer. However, its channel characteristics are poor and there are large burst errors and random errors during transmission. In order to solve this problem, this paper designs a system that can perform time transmission over power lines. In this system, Inter Range Instrumentation Group (IRIG-B) code, Reed-Solomon (RS) code and convolutional code complete the time code encoding. Orthogonal Frequency Division Multiplexing (OFDM) completes the physical layer transmission. The time transfer experiments show that the system has a transmission success rate higher than 99%, and the root meam square (rms) fluctuation is 109 ns.**

Keywords—Time transfer; Power line communication; IRIG-B code;

I. INTRODUCTION

Time is the highest precision achieved among the seven physical quantities [1]. Time-frequency transfer is indispensable in various fields, such as aerospace, deep space communication, geological mapping, navigation, power transmission, all of these fields of time applications are based on the stable and high-precision time-frequency transmission.

The accuracy of time-frequency transmission depends on the carrier, radio, television, optical fiber and other transmission carriers can achieve a high stability and high precision transmission, but the transmission requires a safe environment and stable channel. When in a state of military preparation or war, wireless signal transmission difficulties, strong external interference, the link is vulnerable to damage, when the fiber optic and other carriers cannot work properly, the need for a strong anti-interference ability, link stability, not easy to damage, and easy to lay the carrier instead of work, low-voltage power line has become the best choice. However, because low-voltage power lines are not originally designed to transmit data, their access load equipment has a diversity of channel characteristics constantly changing, so when used as a transmission line, channel noise and electromagnetic radiation bring a large number of burst errors and random errors to signal transmission [3-5]. Therefore, a power line transmission system that can overcome the harsh conditions is needed.

In this paper, we propose a scheme of time transfer in power line with channel coding algorithms, and the performance of the time transfer technique is demonstrated in an experiment.

II. METHODS

A. Timecode Encoder

Fig.1 shows the time code encoder used in this paper, which consists of source coding and channel coding. When external time data is input with a time reference, the time data is encoded as an IRIG-B code and transmitted with the time reference. Next, RS coding and interleaving coding, which can correct burst errors, and convolutional coding, which can correct random errors, are performed to complete the error correction channel coding and generate the timecode bitstream.

IRIG-B code is a time standard format developed by the American Range Measurement Group, which is widely used internationally and is an international common standard. It

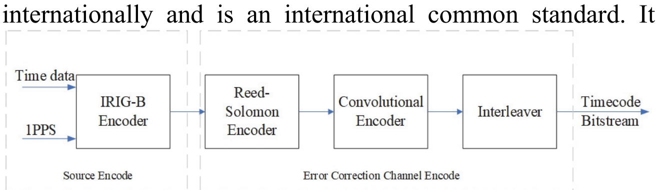

Fig.1. Block Diagram of Time Encoder

carries the time information as shown in Table.1.

RS codes are non-binary and have a divisible maximum

TABLE I. IRIG-B code contains time information with the location of the information

Time information	Bit width	IRIG-B code element location
second	7	2,3,4,5,7,8,9
minute	7	11,12,13,14,16,17,18
hour	6	21,22,23,24,26,27
day	10	31,32,33,34,36,37,38,39,41,42
year	8	51,52,53,54,56,57,58,59

distance making it possible to be an effective response to burst errors. RS codes work in finite fields, and the property of finite fields is that each finite field contains at least one x of an eigenvalue which generates all elements in that field. The encoder designed in this paper is the RS (255, 239) encoder, which has the native polynomial as follows:

$$p(x) = 1 + x^2 + x^3 + x^4 + x^8 \tag{1}$$

The calculated generating polynomials as follows:

$$g(x) = x^{16} + 118x^{15} + 52x^{14} + 103x^{13} + 31x^{12}$$
$$+104x^{11} + 126x^{10} + 187x^{9} + 232x^{8} + 17x^{7} + 56x^{6} \quad (2)$$
$$+183x^{5} + 49x^{4} + 100x^{3} + 81x^{2} + 44x + 79$$

Convolutional codes achieve error-free transmission by adding redundancy to the original signal and combining the current output with the past input. The lower the code rate, the more redundancy is added, and the longer the constraint length, the more closely the information is linked. According to the actual situation, this paper chooses to use a convolutional encoder with a code rate of 1/2 and a constraint length of 7. The corresponding generating polynomial as follows [2]:

$$g(x) = 1 + x + x^{2} + x^{3} + x^{6} \quad (3)$$

$$g(y) = 1 + y^{2} + y^{3} + y^{5} + y^{6} \quad (4)$$

B. *OFDM system*

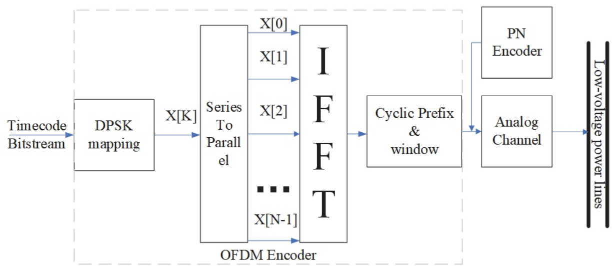

Fig.2. Block Diagram of OFDM System

Fig.2 shows the system model of OFDM. In this system, the temporal data stream is mapped to the corresponding subcarrier to facilitate OFDM modulation, followed by an Inverse Fast Fourier Transform (IFFT) to complete the modulation. A cyclic prefix is added to reduce the inter-symbol interference caused by multipath delay in the PLC system. Subsequently, a window is added to reduce the out-of-band power of OFDM symbols and to reduce the adjacent channel interference. Finally, the data is scrambled using a PN sequence and the data signal with the lowest Peak to Average Power Ratio (PAPR) is selected for transmission.

III. EXPERIMENT AND RESULT

Fig.3 is the test platform used in this paper, using computers to control the start of time transmission, the coding module encodes and transmits through the low-voltage power line, decodes the time information and generates 1pps, and sends it into the frequency counter 53230A together with the original 1pps to complete the time interval measurement. In the case of room temperature 20.3℃ and power line length 50 m, the test was conducted for 2 hours and 7200 data should be obtained, and 7141 data were obtained, as shown in Fig.4, from the data, it is known that the mean value of transmission time interval is 601 ns, the maximum value does not exceed 1us and its rms fluctuation is 109 ns.

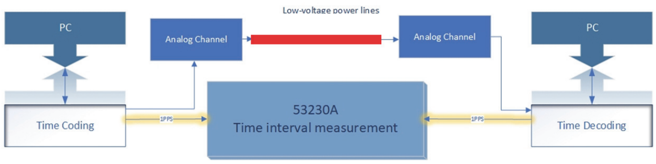

Fig.3. Experimental setup

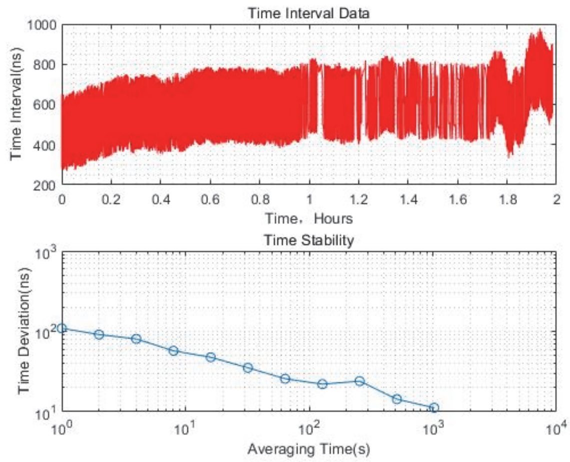

Fig.4. (a)Time fluctuation, (b)Time stablity

IV. CONCLUSIONS

By using the RS-CC code coding form and OFDM, we effectively overcome the random error and burst error in power line signal transmission, accomplish the transmission success rate higher than 99%, rms time fluctuation is 109 ns.

This fluctuation and stability are not the limit of this system, the longer the transmission path may bring more interference, affecting the stability and accuracy. In the future, by adding the bus interrogation mechanism, bi-directional time synchronization can be carried out to further eliminate the impact of time delay brought by the transmission path, and also clock comparison can be carried out to eliminate the impact of the frequency difference between the two ends of the clock to further improve the stability.

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