

A Novel Time Extension Method of the Pulse Laser Ranging System

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Abstract. In order to improve the precision of the laser ranging system, after deeply analyzing various factors that affect the accuracy of pulse laser ranging, a novel time extension method is presented in this paper. Firstly it introduces the laser ranging principle, including pulsed and phase laser ranging principle. Secondly, considering the laser echo time system identification and time interval measurements, the novel time extension method is presented. It uses a capacitor to extend the reflection time to K times, which obviously improves the precision of the pulse laser ranging system and reduces the interval's impact. Then the experimental platform is designed and set up to obtain necessary data. Finally, through the data analysis, the results shows that the accuracy has been improved hundred times compared with the original method.

Introduction

With the development of modern science and technology, people's needs of power transmission line safety are increasing. Setting a laser rangefinder on the transmission line can effectively protect it. The core of laser rangefinder is the measurement of the distance. So improving the measurement accuracy is a very promising work.

In [1,2], some laser rangefinder guidelines based on practical experience and industry standards were given out. In [3,4], two main laser measurements are proposed: pulsed laser measurement method and phase laser measurement method. However, the accuracy of pulsed method is low. In [5-7] a method, called time extension method, is introduced to expand time. It can improve the ranging accuracy, but the effect is not obvious. To solve the problem, the combination of pulse counting method and time extension method is designed. It has higher anti-interference ability and accuracy than other methods, and can realize the on-line monitoring.

In this paper, firstly the laser ranging principle has been detailed introduced, including pulsed and phase two kinds of laser ranging principle, and both advantages and disadvantages have be summarized. Secondly, considering the laser echo time system identification and time interval measurements, the novel time extension method is presented. It uses a capacitor to extend the reflection time to K times, which obviously improves the precision of the pulse laser ranging system and reduces the interval's impact. Finally the experimental platform is designed and set up to obtain necessary data, through the data analysis, the results shows that the accuracy has been improved hundred times compared with the original method.

Pulsed Laser Ranging Principle

Now the development of laser technology has been very mature, laser pulse width can reach tens of nanometers level, its energy is relatively concentrated and the instantaneous power of the laser is relatively large. Therefore, the use of laser pulses to measure the distance can achieve a great advantage: in proximity ranging area it can measure only using target diffuse reflected laser pulses without cooperation objectives and its measure distance can reach very far if there are cooperation goals[8].

Pulse laser ranging launch system emits laser pulse signal (a transmission wave) periodically. Laser pulse signal reaches the measured target and reflects diffusely. The detectors in laser ranging system probe the reflected laser pulse (echo wave). System records laser pulse emission moment t_0 and the detector records laser pulse echo signal moment t_1 . Assuming the distance between target and system is L , then the pulse ranging equation can be expressed as:

$$L = \frac{c(t_1 - t_0)}{2} \quad (1)$$

Factors Affecting the Accuracy of Pulsed Laser Ranging and Ways to Improve

The principle of this pulsed laser ranging system's short-ranging distance is: control system section gives introduction signal to transmission system to transmit pulses. Launch system launches laser pulses periodically. At the same time, launch system sends signals to the identification part to issue a transmission start command signal. Then the identification part receives signal from channel 1 and records the moment. Laser pulse reaches the measured target and reflected diffusely. The reflected laser pulse is received by receiving system. The moment identification section of channel 2 records the moment. At last, time measurement part calculates laser pulse signal transmission and reception intervals $t_2 - t_1$. So data processing system can get the distance $L = \frac{c}{2}(t_2 - t_1)$.

The Effect Moment Identification Accuracy Caused to Pulsed Laser Ranging System

Pulsed laser ranging system changes the distance measurement into measure the time difference between the moment laser pulses emitted and the laser pulses echo accepted.

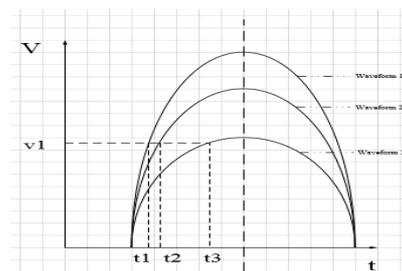


Fig. 1 Laser pulse echo amplitude instability's effect on moment identification

Determination principle of the pulsed laser echo signal's time point is: the arrival time of the echo signal t can be extracted through comparing the laser pulse echo signal's amplified voltage waveform V_{out} with fixed threshold (variable) voltage V_{set} . When the echo signal does not arrive in time, $V_{out} < V_{set}$ the comparator output is low voltage. When $V_{out} > V_{set}$ it illustrates the laser pulse echo signal has arrived. So it is time that convert comparator's output to high voltage. Then

comparator delivers moment on edge t to time interval measurement system as pulse echo signal's arriving time signal.

Time Extension Method

The so-called time extension convert time interval Δt into measurement time $\Delta t'$. They have a definite function $\Delta t' = f(\Delta t)$. So if the result of $\Delta t'$ can be got, the result of Δt can also be got through inverse operation. Use a capacitor in the time interval T_x and use the current size of I_1 to charge the capacitor. Then use the current size of $I_2 = I_1 / K$ to discharge the capacitor. Then measure the discharge time. Capacitor discharge time is longer than the charge time. In the capacitor charging and discharging process, relationship between charge and discharge time is not completely linear, which means existing non-linear relationship. If this capacitor wants to be expanded, the temperature characteristic of the measurement environment becomes particularly important.

Combining time expansion with pulse counting method can largely improve the accuracy. Combined method mainly measure three time intervals. The first one is T_s . According to pulse counting method $T_s = NT_0$, the second and third one are T_1 and T_2 . The key of combined method that can improve the accuracy is to measure T_1 and T_2 . Though using time extension method T_1 and T_2 can be extended. Then use the pulse counting method to measure the extended time again. The specific analysis is: using a constant current I_1 charging capacitor when measure T_1 . Then use a constant current $I_2 = I_1 / K$ recharging capacitor to reach the starting level position after finishing charging process. According to $\frac{I_1 T_1}{C} = \frac{I_2 T_1'}{C}$, $T_1' = K T_1$ can be got. Time is expended K times. The number of pulses is N_1 though using pulse count method. That is $T_1 = \frac{N_1 T_0}{k}$. Similarly $T_2 = \frac{N_2 T_0}{k}$. Then plus previously T_s is obtained. The total measurement time is:

$$T_x = NT_0 + T_1 - T_2 = (N + \frac{N_1 - N_2}{k})T_0 \quad (7)$$

Using this new approach, although still exist the principle errors, the time interval measurement error can reduce K times because time expands K times. For example, when $K = 100$, the resolution of the measurement improves hundred times.

The Test Data and Result

Setting $K = 100$, the experimental result are shown in Table 1.

Table 1 Experimental results chart

Frequency / (Hz)	Cycle/ (s)	T_1 /(s)	T_2 /(s)	Original error/(s)	Optimized theoretical error /(s)	Optimized real error /(s)
50	0.02	0.02	0.004	0.016	0.00016	0.0001631
100	0.01	0.01	0.003	0.007	0.00007	0.0000725
200	0.005	0.005	0.0036	0.0014	0.000014	0.0000148
500	0.002	0.002	0.0012	0.0008	0.000008	0.0000088

As the results of the experimental data shown in table 1, the effect of error reduction is very obvious. So the pulsed laser ranging system that combines counting method with time extension method has a very high accuracy and can be applied to many areas.

Conclusions

Pulsed laser ranging is widely used in many areas such as military, industrial, aerospace, construction and so on. With advances in laser science and technology, laser ranging system will develop towards eye-safe, high accuracy direction. Laser ranging has a very promising prospect.

This thesis completes the following aspects of the work:

1)Detailed introduce the laser ranging principle, including pulsed and pulse two kinds of laser ranging principle

2)Researched two key parts of the technologies: the laser echo time system identification and time interval measurements, and present the time extension method, use a capacitor to extend the reflection time to K times , which obviously improved the precision of the pulse laser ranging system and reduced the interval's impact.

3)Design and set up the experimental platform, obtained necessary data through the experiments. Finally, through the data analysis ,the results shows that the accuracy has been improved hundred times compared with the original method.

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