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Study of Ranging System Using Pseudo-Random Continuous Wave Signal

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Abstract

Pseudo-random signal has potential value as ranging system's signal since it has noise-like character, excellent autocorrelation and large time bandwidth character. The theory of the ranging system based on pseudo-random signal and how system works will be introduced in detail in this paper. We learned that the quality of signal generated by pseudo-random signal generator is very good through observing frequency domain chart, autocorrelation chart and time domain chart of signal. Quite accurate result can be got through dealing with experiment dates. It turned out that pseudo-random signal can be applied efficiently in ranging system and accuracy is quite high in field experiment.

Keywords: *pseudo-random, autocorrelation, ranging, continuous wave*

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1. Introduction

Ranging system which has provided a great convenience to people's life has been used widely in many fields, like automobile crashworthy, the surface measurement. Ranging system can be divided into continuous wave ranging system and pulse ranging system by the type of signal. The main disadvantage of continuous wave ranging system is that distance can't be got directly. If we want get distance information, the frequency of signal has to be changed; however, the corresponding precision is unsatisfactory. Nowadays most of ranging systems take pulse signal which frequency can be constant or modulated as its transmitting signal. The pulse ranging system can get better precision. With the development of technology, people raise a claim for resolution, accuracy and anti-interference to a new level, however, traditional pulse signal can't meet these demands. Signal power has to be stronger enough if target is far, while high resolution request narrow pulse width, tradition pulse system can't satisfy pulse width and signal power at the same time when it reach to some level.

Pseudo-random signal is a noise-like signal which has a certain period. Its autocorrelation character is very sharp which is similar to random noise, however, pseudo-random signal can change based on certain rules, so it's not real random signal. People has applied pseudo-random signal into ranging system, but in most case people use it to modulate pulse signal as references [1-3] mentioned. There is also ultrasonic ranging system which use pseudo-random signal to modulate ultrasonic signal, as inference [4] mentioned.

We bring a ranging system based on pseudo-random continuous wave signal in this paper. There are some confirmatory experiments and similar products in developed countries like Switzerland as inference [5] mention, however, similar research have not done in China.

The ranging system we designed has three remarkable advantages as fellow: the transmitting signal of ranging system is pseudo-random continuous wave signal which could avoid pulse signal impair transmitter and receiver effectively because of the character of pseudo random signal; This method assure that the distance result is sole by getting cross-correlation function maximum, also avoid the ambiguity of distance function; the anti-interference of our ranging system is very strong because of pseudo-random signal's noise-like character.

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2. Ranging Principle

The principle of most ranging system is that system sends some kind electromagnetic wave, the signal reflects when there is a target in front of propagation path, and then we could get target's distance information by calculating the delay τ between echo signal and transmitting signal according to Equation (1).

$$S = \frac{c\tau}{2} \tag{1}$$

Where c is the velocity of propagation of electromagnetic wave.

According to general conclusion of the principle of signal detection, if ranging system takes pseudo-random continuous wave as its transmitting signal, the optimal receiver of the ranging is a cross-correlation receiver. Then target's accurate distance information could be got by processing the cross-correlation function of echo signal and transmitting signal.

Cross-correlation function of echo signal and transmitting is showed as fellow:

$$R_{xy} = \frac{1}{T}\int_{T} y(t)x(t+\tau)d\tau \tag{2}$$

Where y (t) is echo signal, x (t+τ) is transmitting signal, T is sampling period.

We can get target's delay by measuring position of maximum value of correlation function, and then we could get target's distance information.

3. System Design

The structure chart of our ranging system is showed as Figure 1. Pseudo-random signal generator and clock worked together to generate pseudo-random signal, then spited the pseudo-random signal into two parts. One part was transmitted by transmitter after amplifying by microwave amplifier. Signal reflected when there was a target in front of its propagation path, then be received by receiving antenna. Echo signal was sent to digital sampling oscilloscope after being processed by low noise amplifier. The other part of pseudo random signal was sent to digital sampling oscilloscope directly.

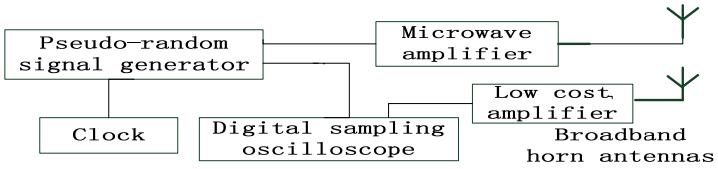

Figure 1. Structure Chart of Pseudo-random Ranging System

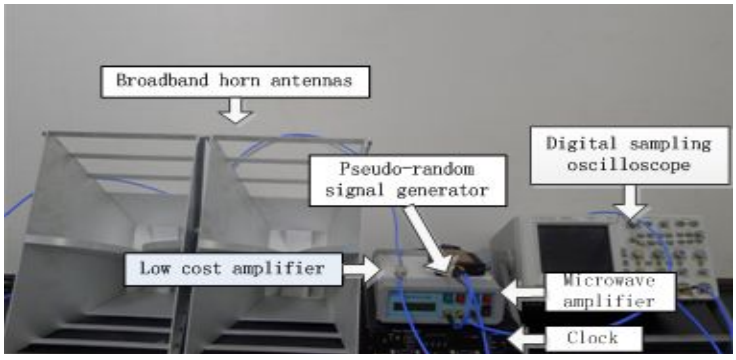

Figure 2. Physical Chart of the Ranging System

The physical map of our ranging system is showed as FIgure 2. This system is made up of clock, pseudo-random signal generator, microwave amplifier, broadband horn antennas, low noise amplifier and digital sampling oscilloscope. Pseudo-random signal generator (TG2P1A), the range of signal bandwidth is from 50M to 12.5G. Clock (TG1C1-A) work together with pseudo-random signal generator which the range of frequency is from 500M to 13.5G. Broadband horn antennas (LB-530), the range of system is 0.5~3GHz. Digital sampling oscilloscope (MS06104), the sampling frequency is 4GHz. The gain of microwave amplifier is variable.

4. Experiment and Analysis

We placed a strong reflector which is a metal plate in front of antennas in order to get strong echo signal. Pseudo-random signal generator and clock worked together to generate the pseudo random signal which bandwidth is 550M. Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 can be got through processing the data with matlab program, which we got through digital sampling oscilloscope.

We could observe the time domain graph of pseudo-random signal through digital sampling oscilloscope, as showed in Figure 3. it proved that signal source generated pseudo-random signal.

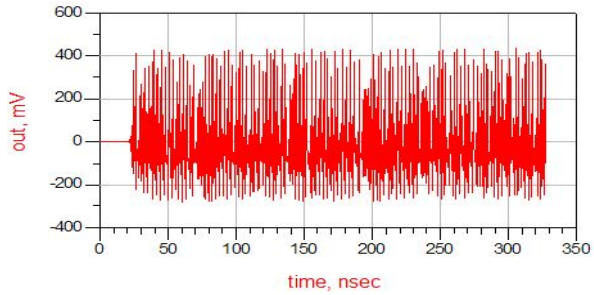

Figure 3. Time Domain Graph

Picture 4 is spectrum graph of pseudo-random signal, it's easy to observed that the bandwidth is 550M.

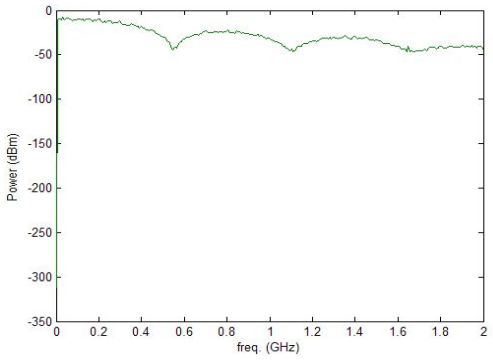

Figure 4. Spectrum Graph

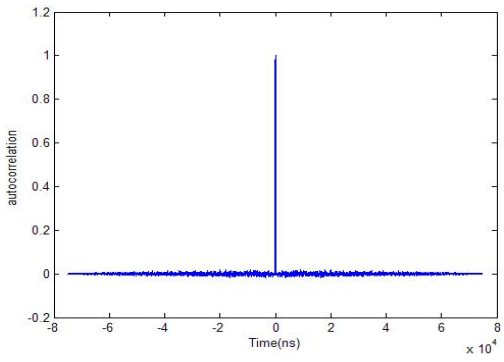

Figure 5. Autocorrelation Graph

Figure 5 is the autocorrelation graph of pseudo-random signal, we knew that the main lobe was tall and slim, side lobe was short.

We conducted three representative experiments which target's distances from were 570cm, 611cm and 671cm at last. The distances we got through experiments were 570cm,

611.3cm and 671.3cm, the corresponding cross-correlation graphs are Figure 6, Figure 7 and Figure 8. We made about one hundred experiments; the error was within 1.0cm. According to experiments we could get the conclusion safely that using pseudo-random signal in ranging system is practical, and a satisfying precision could be got.

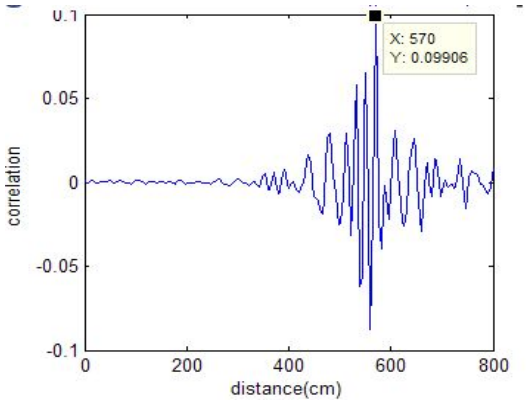

Figure 6. Cross-correlation Graph of First Group

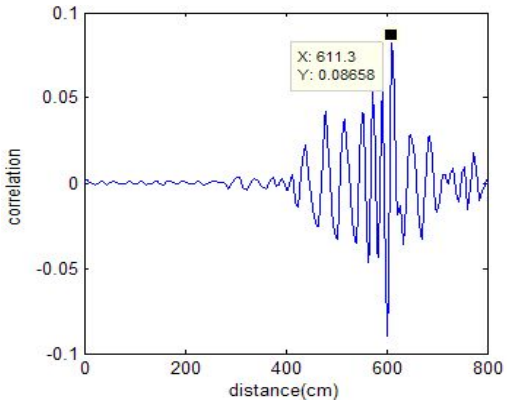

Figure 7. Cross-correlation Graph of Second Group

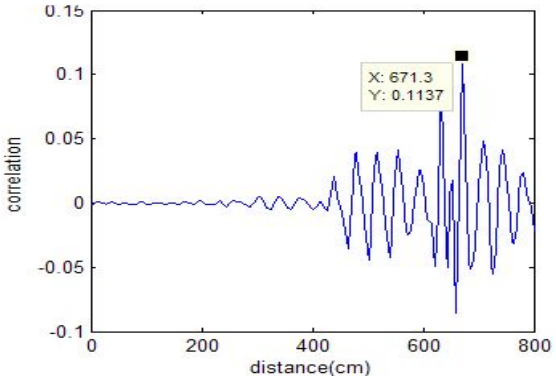

Figure 8. Cross-correlation Graph of Third Group

5. Conclusion

Pseudo-random signal has noise-like character, large time bandwidth character and excellent autocorrelation. We applied it into ranging system, and system turned out feasible. We could get the conclusion safely that it's practical to use pseudo-random signal in the ranging system.

Acknowledgements

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