Research on Digital Pulse Compression Technology of Overlapping Data Splicing

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Abstract. Digital pulse compression technology is an effective technology to solve the contradiction between the maximum operating distance and the range resolution of sonar. However, in practical application, when the amount of data to be processed is large and the segmented processing is needed, the data segmentation may be unreasonable, resulting in the weak peak value of the signal after pulse compression, thus affecting the detection results. This paper introduces a method of overlapping data splicing. By improving the correlation between signal and matched filter, the problem of unreasonable data segmentation is effectively solved.

1. Introduction
With the strategic transformation of various navies and the development of modern science and technology, new underwater weapons are developing in the aspects of long range, fast speed and good concealment performance, which also puts forward higher and higher requirements for sonar system to detect underwater targets. The main technical index to measure the performance of sonar system is the maximum range and range resolution. The maximum operating distance refers to the maximum distance that sonar can effectively find targets and measure their data under certain conditions. The range resolution refers to the resolution of sonar system to two adjacent targets in space[1]. In order to improve the range resolution, the signal is required to have a large bandwidth. In order to increase the maximum operating distance, the signal is required to have a large energy. However, the peak power of the signal transmitter cannot be infinitely increased. In practice, the average power of the transmitted signal is often increased by increasing the pulse width of the signal to achieve the purpose of increasing the maximum operating distance, which requires the signal to have a large Time width, bandwidth product. It can be seen from the theory of signal and system that the time bandwidth product of common signal is a constant, so it is impossible for signal to have large time bandwidth and bandwidth at the same time[2]. In order to solve this contradiction, a new technology pulse compression technology must be adopted.

Pulse compression technology[3-5] can effectively solve the contradiction between the maximum operating distance and range resolution of sonar. By using pulse compression technology, the signal with large time width and bandwidth can be transmitted at the transmitting end to improve the maximum operating distance of the signal. At the receiving end, the wide pulse signal can be compressed into a narrow pulse to improve the range resolution. When sonar detects the target, it needs to process the data received by sonar in real time, which requires data segmentation and splicing. Simple data segmentation processing may result in the same pulse signal being divided into two parts, thus affecting the pulse compression result. In order to solve this problem, this paper takes LFM
signal[6-8] as the research object and adopts overlapping data splicing method. The feasibility of this method is verified by MATLAB simulation.

2. Principle of digital pulse compression

Digital pulse compression refers to the use of digital signal processing technology to complete the correlation matching, usually using the matching formula of time-domain pulse compression and frequency-domain pulse compression. Among them, the time-domain pulse compression directly convolutes the echo signal received by sonar. When the convolution speed is less than the AD sampling frequency, the data cannot be processed in real time. Therefore, it is necessary to reduce the amount of calculation and adopt the frequency-domain digital pulse compression algorithm with fast operation speed.

Frequency domain digital pulse compression technology is to complete the pulse compression of digital signal through frequency domain matched filtering technology. Firstly, the frequency spectrum of digital input signal is obtained by Fourier transform (FFT), then it is multiplied by the complex number of frequency response of matched filter, and then the multiplied signal is transformed by inverse Fourier transform (IFFT), that is to say, the signal after pulse compression is obtained. The whole process can be expressed as follows:

\[
y(n) = IFFT \left[ s(w) \cdot h(w) \right] = IFFT \left[ FFT \left( s(n) \right) \cdot FFT \left( h(n) \right) \right]
\]  

The realization block diagram of frequency domain digital pulse compression is shown in Fig. 1.

![Frequency domain digital pulse compression block diagram](image)

3. Pulse compression simulation

Fig. 2 is the simulation result of frequency-domain pulse compression of single cycle ideal believe FM signal. Fig. 2 is the simulation figure of ideal LFM digital signal, Fig. 2 is the simulation figure of frequency-domain pulse compression of LFM signal. Fig 3 is the simulation result of frequency-domain pulse compression of LFM signal after single cycle superimposed white noise. Fig 3. The figure above is the simulation figure of LFM digital signal with superimposed white noise, and the figure below is the simulation figure of frequency-domain pulse compression of LFM signal with superimposed white noise.
It can be seen from Fig. 2 and Fig. 3 that the frequency domain pulse compression technology can effectively compress the wideband LFM signal into a narrowband signal, and the peak position of the narrowband signal is just at the end of the wideband LFM signal.

4. Data splicing method
In practical application, the signal received by sonar generally needs real-time processing, which inevitably requires the use of data segmentation and splicing technology. The conventional data segmentation and splicing method is shown in Figure 4. The same pulse signal may be divided into two segments. When processing the data for pulse compression, the two segments of data are partially related to the matched filter, which will affect the peak position after pulse compression, thus affecting the determination of the peak position after pulse compression.

In order to solve this problem, this paper proposes a method of overlapping data segmentation and splicing, as shown in Figure 5, which is the overlapping part of the two sections of data. Using the method of overlapping data segmentation and splicing can ensure that each complete pulse is in the same data section, fully related to the matched filter, and the peak position energy value is large after pulse compression.
5. Data splicing simulation research

Fig. 6 is the simulation result of pulse compression processing for two groups of digital sampling signals using conventional data division and splicing method, and Fig. 7 is the simulation result of pulse compression processing for two groups of digital sampling signals using overlapping data division and splicing method.

It can be seen from Fig. 6 that when the same pulse signal is divided into two parts, the correlation with the matched filter decreases. When the pulse compression technology is used to compress the narrow-band signal, the energy at the peak of the narrow-band signal decreases or does not exist, so the pulse position cannot be effectively identified.
It can be seen from Figure 7 that when the pulse is in a data processing section, the data is highly correlated with the matched filter, and the peak energy after pulse compression is also large. The pulse position can be effectively identified by judging the peak energy at the adjacent position.

To sum up, the overlapping data splicing method can effectively solve the irrationality of the conventional data segmentation splicing method, improve the correlation between the segmented data and the matched filter, increase the energy value at the peak position after pulse compression, and improve the ability to identify the pulse signal.

6. Conclusion
Pulse compression technology not only reduces the power requirements of sonar transmitter, but also effectively solves the contradiction between the maximum operating distance and range resolution of sonar, which is widely used in sonar signal processing. Using overlapping data segmentation and splicing technology for digital pulse compression processing can improve the matching degree of signal and filter, and improve the resolution ability. In this paper, matlab simulation is used to verify the effectiveness of overlapping data splicing method in the need of segmented pulse compression processing.

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