TEST Engineering & Management

July - August 2020
ISSN: 0193-4120 Page No. 6268 - 6273

Simulation System of Pulse Bioelectrical Signal Processing Based on Bioelectrical Signal

Li Wang*
School of Electrical & Electronic Engineering, Baoji University of Arts and Sciences, Baoji 721016, Shaanxi, China

Article Info
Volume 83
Page Number: 6268 – 6273
Publication Issue:
July - August 2020

Article History
Article Received: *25 April 2020*
Revised: *29 May 2020*
Accepted: *20 June 2020*
Publication: *28 August 2020*

Abstract

Bioelectrical signals can be divided into continuous signals and pulse signals.Conventional bioelectrical signal signals include incoherent pulse signals, coherent pulse signals, staggered periodic pulse signals, stepping frequency pulse signals, linear frequency modulation signals, nonlinear frequency modulation signals, phase coded signals, etc. Here we mainly introduce commonly used chirped signals, nonlinear frequency modulation signals, phase coded signals, etc.In order to further improve the processing capacity of bioelectrical signal, the detailed analysis algorithm based on the bioelectrical signal processing model is used to implement the simulation verification model of the algorithm, such as pulse pressure, MTI, MTD, CFAR, ranging, velocity measurement, and measurement.

Keywords: *Continuous Wavelet, Transformation Algorithm, Pulse Doppler, Bioelectrical Signal Processing;*

1. Introduction

Biological electrical signal processing is the purpose of eliminating all unnecessary signal and interference, extract or improve the generated target echo signal, and the use of signal processing in the process of some key technologies, such as digital orthogonal dual-channel processing, pulse compression technology, cancel the fixed target technology, mobile target display technology, moving target detection technology, constant false alarm processing and pulse accumulation.As the processing process of modern bioelectrical signals is becoming more and more complicated, it is difficult to process them with simple and intuitive analysis methods, so computers are often needed to simulate the function and performance of the system.It is convenient, flexible and economical to simulate the bioelectrical signal system by computer.MATLAB provides a powerful simulation platform for most bioelectrical signal systems to provide convenient and fast calculation[1].

2. Bioelectrical signal processing simulation system

2.1. Digital orthogonal double channel processing

Orthogonal dual-channel processing refers to the processing of if echo signals by two similar branches.The only difference is that the phase of the reference phase voltage is 90 degrees. The two paths are called:

It branches off in phase channel - I

Orthogonal channel - Q branch

The traditional method USES simulated orthogonal two-channel processing.Orthogonal to the I and Q channel processing mixed receiver of intermediate frequency echo signal output and the bi-directional orthogonal coherent signal (using analog multiplier), and low pass filtering, get two I and Q baseband signal, and then gives the digital quantity of the in-phase component and quadrature component, through orthogonal dual-channel A/D conversion and processing of advantage (relative to the single channel processing)[2].

The purpose of pulse compression is to concentrate all the energy of a single bioelectrical signal to obtain the maximum output SNR.By means of matched filtering, a compressed network matching the transmitting signal frequency is set up in the receiver to change the modulated wide pulse echo signal into narrow pulse and maintain a good range resolution.

2.2. Application of pulse pressure network adaptation

A pulse compression network is actually a matched filter network. The matched filter is the optimal linear filter under the maximum output SNR criterion. According to the matching theory, the transmission characteristics of the matching filter are as follows:

$$H(\omega) = KS^*(\omega)e^{-j\omega t_0} \quad (1)$$

Time domain representation (impact response) is:

$$h(t) = Ks^*(t_0 - t) \quad (2)$$

Using FFT algorithm can greatly reduce the amount of computation and meet the requirements of real-time processing.Frequency domain matched filter: after spectrum multiplied by Fourier transform, simple frequency domain analytic expression is used.Using FFT algorithm can greatly reduce the amount of computation and meet the requirements of real-time processing.A very low side lobe can be obtained by opening the window, as shown in Figure 1.

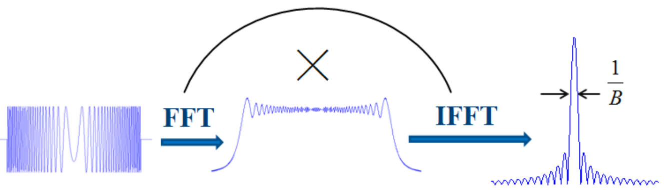


Figure 1. Frequency domain matched filtering algorithm.

As shown in Figure 1,K is the normalized amplitude constant, is the transmitted signal, and x (t) echo signal.There are two matched filtering methods for chirped signal: time domain matched filtering and frequency domain matched filtering.Time-domain matched filtering: sliding filtering.Due to the large amount of computation, it is difficult to meet the requirements of real-time processing. Frequency domain matched filtering: Spectral multiplication after Fourier transform[3].

2.3. Display MTI for moving targets based on bioelectrical signals

Moving target display is a moving target display that USES MTI filter to filter out the corresponding clutter in order to improve the performance of target detection.The spectral line of fixed target is located at integer multiples of pulse repetition frequency, while the echo signal of moving target has Doppler shift.The moving target display filter utilizes the difference between moving target echo and clutter in the spectrum to extract signals effectively by suppressing clutter.

The most direct method is to subtract the echo signals of adjacent repeating cycles so that the amplitude of the echoes of fixed targets remains unchanged and cancel each other out. After the echo of moving target is eliminated, the amplitude part of adjacent repetition period changes. This traditional non-recursive primary canceller (i.e., double pulse canceller) was used in the experiment.The structure is shown in Figure 2:

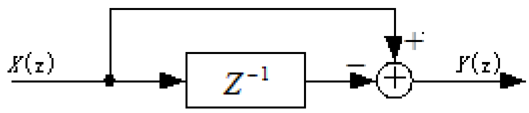


Figure 2. Double pulse cancellation structure diagram based on bioelectric signal algorithm.

The frequency response is shown in Figure 8.There is a gap at the integer multiple of pulse repetition frequency, so the echo of fixed target will be greatly suppressed after passing through THE MTI filter.Ideally, the output is zero.MTD is also a combination of coherent accumulation and Doppler filtering.The purpose of coherent accumulation is :1.Collect the energy of all signals emitted by bioelectrical signals in multiple pulse repetition cycles/FM cycles to obtain the maximum output SNR.2. Reduce the impact of target RCS fluctuation on target detection.Moving target detection is also called moving target detection. According to the optimal linear filtering theory, the moving target

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 6268 - 6273

echo is detected under the clutter background.In addition to the clutter rejection filter, a filter matching the burst signal should also be connected in series.MTD USES the coherence of echo sequence for coherent accumulation.In practice, a set of adjacent and partially overlapping filter Banks are used to cover the whole Doppler frequency range, namely, narrow-band Doppler filter Banks.The implementation of N adjacent Doppler filter Banks is made up of N output transverse filters (N pulses and N-1 delay lines) weighted by different pulses.K represents the filter with labels from 0 to N-1. Each K value corresponds to a set of different weights, corresponding to a different Doppler filter response.The filter response shown in Figure 10 is the filter frequency response of each marker K weighted by N = 8, and K is 0-7.The frequency range of the filter is 0 ~ FR. In the simulation experiment, FFT is usually used to realize the filter[4].

2.4. Biological electrical signal processing CFAR alarm detection of constant deficiency

After pulse - echo compression, MTI and MTD filtering of bioelectric signals, the existence of targets is determined: detection beyond threshold value. In this paper, constant false alarm Probability detection (CFAR) is used to calculate the detection threshold as a pre-determined false alarm rate to keep a constant value in the bioelectric signal receiver. The detection principle is as follows:

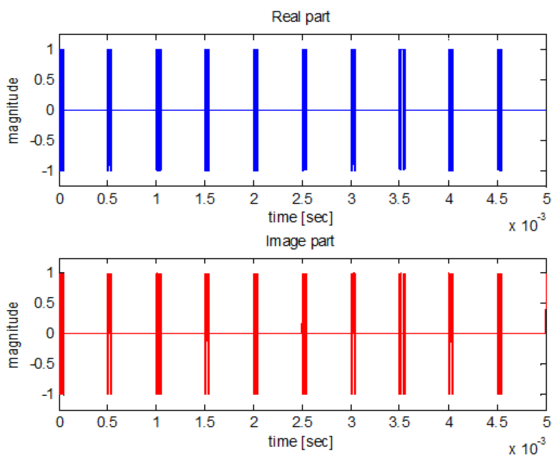


Figure 3. Schematic diagram of CFAR detection.

As shown in Figure 3 above, the key point of constant false alarm detection is to determine the threshold value of constant false alarm detection.Equation 3 shows the relationship between threshold VT and false alarm probability Pfa:

$$V_T = \sqrt{2\psi^2 \ln\left(\frac{1}{P_{fa}}\right)} \quad (3)$$

Among them, for the noise power, because the noise power is constantly changing, in order to maintain a constant false alarm probability, the threshold must be constantly updated according to the estimation of noise variance. Constant false alarm probability (CFAR) is the process of maintaining a constant false alarm probability by constantly changing the threshold.But the intensity of the noise is unknown and must be estimated. Due to the large amplitude of the target signal, in order to eliminate the impact of the target signal on noise estimation, there are protection units around the detected target, which do not participate in noise power estimation[5]. The schematic diagram is shown in Figure 3.

3. Establish a bioelectrical signal processing simulation system

3.1. Pulse pressure preparation

Before pulse compression, the matching filter of corresponding bioelectrical signal is obtained.In practical engineering, pulse compression is often processed in the frequency domain, because FFT algorithm can be used to improve the calculation speed, and then the echo of bioelectrical signal is multiplied by the frequency domain response (pulse compression coefficient) of the matching filter.After IFFT transformation, the result of pulse compression can be obtained without convolution processing, which greatly reduces the computation.Therefore, in the simulation of pulse compression processing, the matching filter or pulse compression coefficient of pulse compression processing should be obtained first. It is relatively simple to find the compression coefficient of chirped signal. The ideal chirped signal can only be conjugated.

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 6268 - 6273

Matlab was used to simulate the pulse compression steps of a chirped signal:

Generate ideal chirped signal;

The signal is demodulated by orthogonal demodulation.

Generate the ideal chirp compression factor. In this step, the matching filter of orthogonal demodulation signal FBB is obtained first, and then the compression coefficient of pulse is obtained by discrete Fourier transform[6].

Generate an ideal echo signal (signal) and perform orthogonal demodulation of the signal.The ideal echo signal is the echo signal received by the bioelectric signal in the pulse repetition period.

Signal_fft is obtained by discrete Fourier transform of the echo signal, then signal_FFT is multiplied by the frequency domain response (pulse compression coefficient) of the matching filter, and then inverse Fourier transform is used to obtain the pulse compression result.

Let the bioelectrical signal be the chirp signal.The specific parameters are as follows: pulse width 10° S, central frequency 10MHz, and FM bandwidth 2MHz.The sampling frequency of bioelectric signal is 40 MHz, and the intermediate frequency is orthogonal down-conversion.

3.2. Echo accumulation module

At present, bioelectric signals are detected on the basis of multi-pulse observation. The accumulation of multi-pulses can effectively improve the signal-to-noise ratio (SNR), thus improving the detection ability of bioelectric signals.The accumulation process can be completed before envelope detection, which is called pre-detection accumulation or intermediate frequency accumulation. When the signal is accumulated in the intermediate frequency, it is required that there is a strict phase relation between the signals, that is, the signal is coherent, so it is also called coherent accumulation. In addition, the accumulation process can be completed after envelope detection, which is called post-detection accumulation or video accumulation. Since the signal loses phase information after envelope detection and only retains amplitude information, the detected accumulation processing does not require the existence of strict phase relationship between signals, so this accumulation is also called incoherent accumulation. Non-coherent accumulation is realized by means of tap delay line accumulation and feedback accumulation.

The cumulative pulse number N should be equal to the target echo number when the antenna beam sweeps a point target, that is, the target echo number when the beam sweeps a point target, that is, in Formula (3) :Biwa is the antenna azimuth beam width theta Angle, the antenna scanning pulse repetition period; Tic is the time it takes the antenna to scan for a week;PRI is the pulse repetition period.The noise inside the bioelectrical signal receiver is generally considered as Gaussian white noise, which is a stationary random process. The amplitude modulation of echo pulse is also modulated by the bidirectional field intensity lobe of the antenna.If the antenna field intensity lobe pattern (unipass) is in the form of sinx/ X, the following pulse is added to the antenna main lobe:

3.3. Constant false alarm Processing (CFAR) module

There are many ways to deal with frequent false alarms. From the perspective of the big classification, there are the so-called mean class CFAR, ordered statistics class CFAR and clutter graph CFAR.Mean class CFAR includes a variety of implementation methods, such as cell average mode, two-way average unit size selection method, two-way average size selection method, etc.The basic principle is the same.

Matlab simulation constant false alarm processing steps:

The point target echo superposed by Rayleigh clutter and thermal noise is generated. In this step, gaussian thermal noise and Rayleigh clutter are first generated according to the above method, and then superimposed with the point target echo. During the

Published by: The Mattingley Publishing Co., Inc.

superposition, amplitude of Rayleigh clutter and Rayleigh clutter should be weighted.

Using Rayleigh clutter and thermal noise superposition method, the point target echo is processed with continuous false alarm. This step starts by determining the number of reference cells. If the number of reference cells is 16, then the noise mean constant of the first point is processed by level 16 noises, and the noise mean constant of the second point to 16 is the noise before and after 16 points.

To sum up, the average noise of normal data points is determined by the noise before and after 16 points, and the last 16 points after constant false alarm processing are the same as the first 16 points.The final output signal is the ratio of each detection unit to the estimated clutter mean.

3.4. Information processing and simulation in the working process

When the bioelectric signal works, the transmitter sends a series of high-frequency pulses with a certain repeating period into space through the antenna.If there is a target in the electromagnetic wave propagation process, the bioelectric signal can receive the target's echo back.Because the echo signal propagates between the bioelectrical signal and the target, it will lag behind the transmitting pulse for a period of time.As shown in Figure 13, the energy of electromagnetic waves travels at the speed of light.If the distance to the target is R, then the distance traveled is the product of the speed of light., that is:

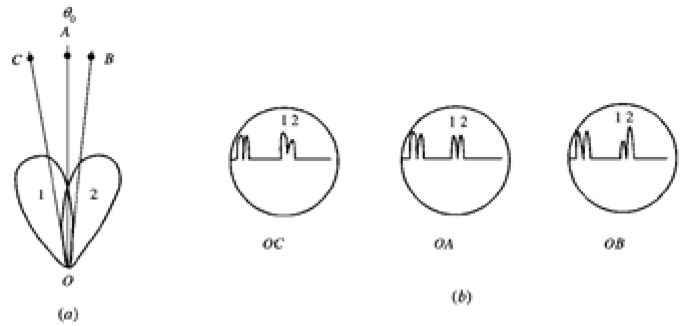
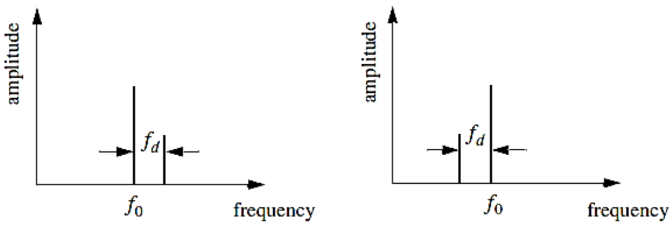


Figure 4. Principle of ranging by bioelectrical signals.

As shown in FIG. 4, the distance corresponding to the round-trip delay time (pulse period) is called the non-fuzzy distance of bioelectric signals.Since the received echo may be regarded as the echo of the transmitting pulse closest to it, it may also be the echo of the previous transmitting pulse. In this case, some bioelectrical signals need to determine the location of a target in addition to its location.The velocity of the target motion can be determined by measuring the change in distance between time intervals.

3.5. Application of target distance differential method in velocity measurement

This method is called target distance differential velocity measurement. This method of measuring velocity is time-consuming and cannot measure its instantaneous velocity. In general, the accuracy of the measurements is also poor and the data can only be used as rough surfaces. The common method of speed measurement is doppler frequency measurement. We know that when there is a relative velocity between the target and the bioelectric signal station, the carrier frequency of the received echo signal will shift relative to the carrier frequency of the transmitted signal.This frequency shift is known in physics as the Doppler shift. Its value is shown in Figure 5:



(A) Close to the target (B) behind the target

Figure 5. Doppler shift spectrum of the received bioelectrical signal.

As shown in figure 5, system-level simulation plays an extremely important role in bioelectrical signal processing systems.System-level simulation ensures the correct design of the product at the highest level. Due to the complexity of the external field simulation real battlefield electromagnetic environment is very difficult, and expensive, so using computer simulation technology of

Published by: The Mattingley Publishing Co., Inc.

controllable, repeatability, non-destructive, security, biological electrical signal simulation of electronic warfare equipment characteristics and advantage of the economy, and its application technology tactics effectiveness evaluation is the study of current and future important means of biological electrical signal electronic countermeasures.

As can be seen from the composition diagram of PD bioelectrical signal system, the bioelectrical signal of the received echo signal can be divided into two signals and the signal difference, namely a linear frequency modulation signal and a bioelectrical signal transmission signal. The difference between the beam and the beam in the signal processing method is exactly the same.After the completion of CFAR, amplitude and difference Angle measurement will be carried out, and the result after beam processing will be used for ranging and velocity measurement.

4. Conclusion

Matlab is used to simulate the bioelectrical signal processing system, and the system model can be established quickly.The design concept can be embodied in any detail. The modeling time of this model is short, the model is simple, clear and the calculation precision is high. At the same time, it can be very much at any stage of system design. Easily modify models, evaluate results, and validate system behavior. In this paper, the pulse compression bioelectrical signal is taken as an example, and the bioelectrical signal processing simulation method based on Matlab has achieved good results.By analyzing the biological electrical signal system simulation and performance evaluation, on the deep understanding of the biological electrical signal system had certain, and simple to learn the biological electrical signal system the principle of each part, including biological electrical signal transmitter, biological electrical signal receiver, an antenna, target echo, signal processor, and data processor.Have a certain understanding of pulse pressure, MTI, MTD, CFAR, ranging, velocity measurement, Angle measurement and other principles.On this basis, this paper discusses the simulation methods of bioelectrical signal system, including functional level simulation, signal level simulation, distributed interactive simulation and semi-physical simulation, mainly using Matlab programming to realize the functions of each part of the bioelectrical signal system.

Acknowledgements

This work was supported by Special Project of Scientific Research of Education Department of Shaanxi Province, China (19JK0038)

References

[1] Bida Y. The development of a microcomputer-based physiological signal processing device[J]. Journl of Guiyang Medical College, 1991.

[2] Mehmet Gündoğan, Mustafa Özden, İrfan Karagöz. An advanced ABR measurement system design based on C6713 digital signal processor[C]// Signal Processing & Communications Applications. IEEE, 2011.

[3] M. Gundogan, M. Ozden, I. Karagoz. An advanced ABR measurement system design based on C6713 digital signal processor[J]. 2011.

[4] Sornmo Leif, Laguna Pablo. Bioelectrical signal processing in cardiac and neurological applications[J]. Bioelectrical Signal Processing in Cardiac & Neurological Applications, 2005:vii–xiii.

[5] Merlet I, Garcia–Larrea L, Grégoire M. C, et al. Source propagation of interictal spikes in temporal lobe epilepsy. Correlations between spike dipole modelling and [18F]fluorodeoxyglucose PET data[J]. Brain(2):377-392.

[6] Barry R. Greene Φ, Stephen Meredith Richard, Richard B. Reilly, et al. ISSC 2004, Belfast, June 30 - July 2 A novel, portable eye tracking system for use in Schizophrenia Research Barry R. Greene[J]. 2004.