Project2

Motion detection via communication signals

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Learning objects:

1. master the basic working principle of the passive radar detection.
2. Using matlab to obtain the distance and velocity of the objects via time delay and frequency shift.
3. Learn to draw the thermal image and explain the meaning of it.

Introduction:

Passive radar first receives a reference signal sent from a transmitter. Then， the transmitted signals through a direct path (commonly referred to as "reference channel"). At the same time, the receiver will receive the reflected signal scattered by the target. The target range and Doppler shift can be estimated by calculating the time difference and frequency difference between the signals sampled from the two channels.

The formula to calculate the distance and velocity of the object is enumerated as follows:

Distance=time delay multiplies velocity of light

Velocity=wavelength multiplies frequency shift, divided by double cosine of the angle between radar and base station from the object.

In order to find the most suitable time delay and frequency shift, we import a ambiguity function. It is the convolution of the two signals from reference signal and measuring signal after preprocessing, frequency delay and low-pass-filtering. The bigger the absolution of the ambiguity function, the better the proximity between the given and the real time delay and frequency shift. The ambiguity is similar to the self-correlation of the two signals. It is to determine the extent of the positive relationship between the inputs.

We have totally three tasks:

1. Obtain the time and frequency spectrums of the original reference and measuring signals. And those after frequency delay and low-pass-filtering. Totally 12 plots.

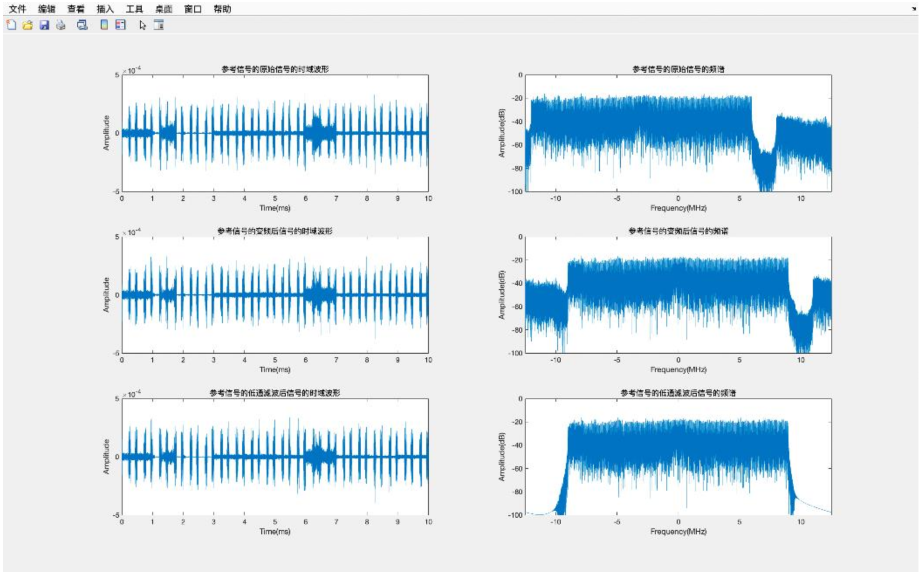
2. Obtain the distance-Doppler plots of the time periods 0-0.5s、2-2.5s、5-5.5s、7-7.5s

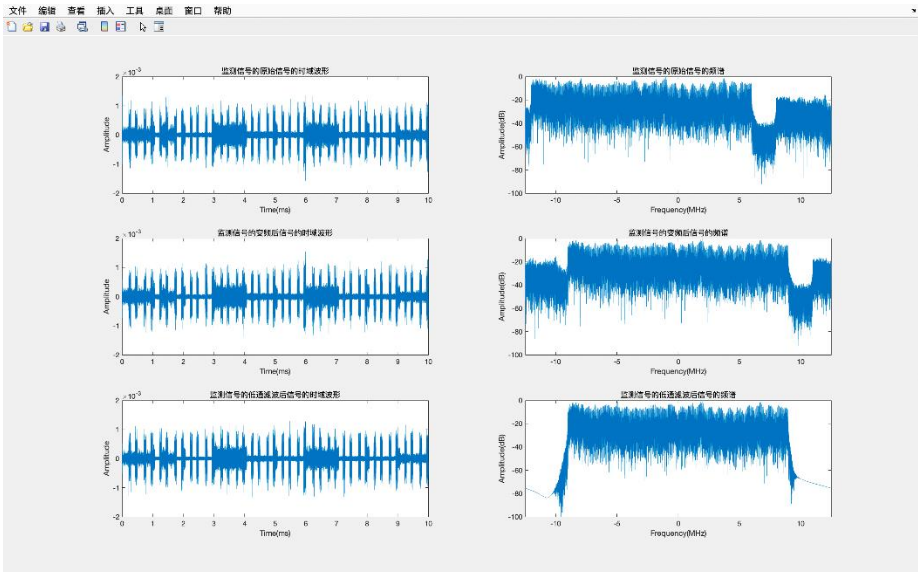
3.For CIT=0.5s the sliding window, obtain 10s of data each slide 0.5s time-Doppler spectrum.

Results and analyses:

Task1:

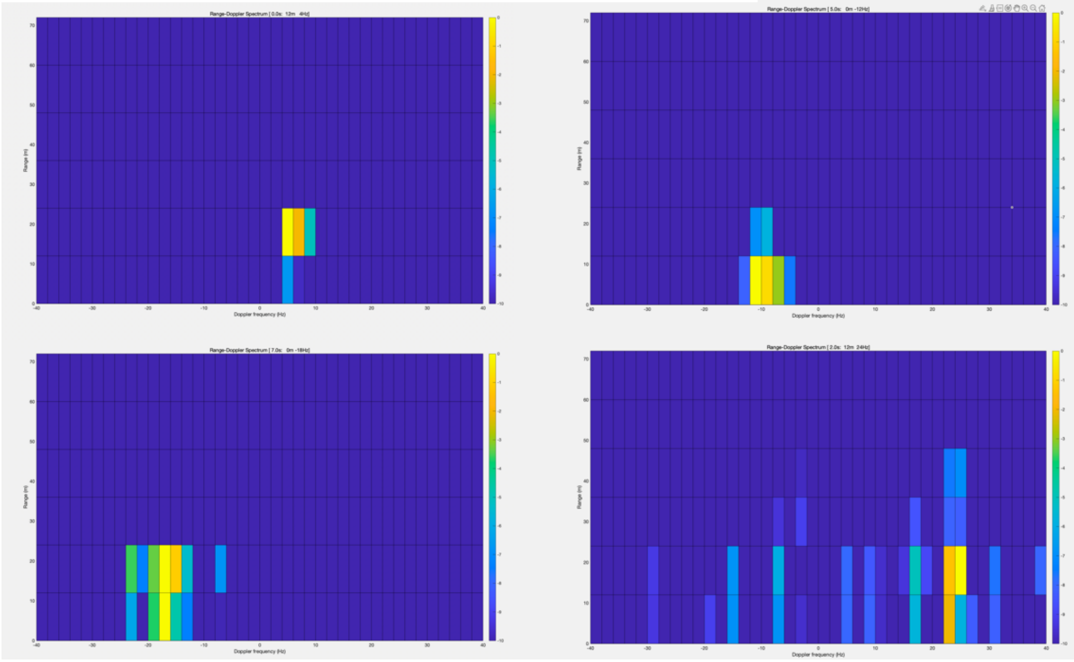
We receive the baseband signal with frequency of 2110-2130MHz and 2130-2135MHz. Before processing the signal, we first centralize the signal with frequency of 2110-2130MHz. Then we use a low-pass filter to get rid of signal with high frequency. The result is shown below.





Task2:

We then calculate the Cor function in 0-0.5s, 2-2.5s, 5-5.5s and 7-7.5s. The figure is shown below:



Task3:

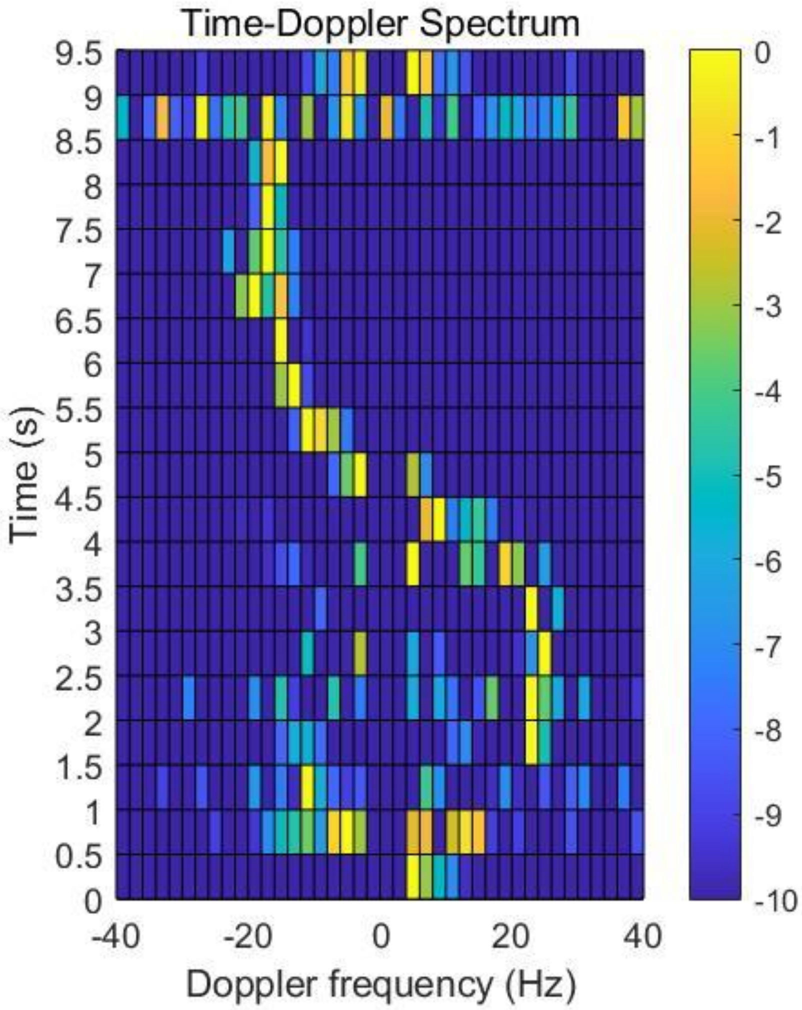
The fragment within [t, t +T] time of the two received signals is taken to calculate the Cor function. The value of the Cor function is obtained by traversing all possible (c, d), and the corresponding (c, d) of the maximum value is selected as the estimated value.

$$\boldsymbol{Cor}(\boldsymbol{c},\boldsymbol{d},\mathrm{t}) = \int_{\boldsymbol{t}}^{\boldsymbol{t}+\boldsymbol{T}} \boldsymbol{y}_{\mathrm{sur}}(\boldsymbol{t}+\boldsymbol{c})\boldsymbol{y}_{\mathrm{ref}}^{*}(\boldsymbol{t})\boldsymbol{e}^{-\boldsymbol{j}2\boldsymbol{\pi}\boldsymbol{d}\boldsymbol{t}}\boldsymbol{dt}$$

$$\boldsymbol{g}(\boldsymbol{d},\boldsymbol{t}) = \max_{\boldsymbol{c}} |Cor(c,d,\boldsymbol{t})|$$

Vectorization g(d, t).

Draw the change relation of g(d, t) with time after vectorization. Then, we get:



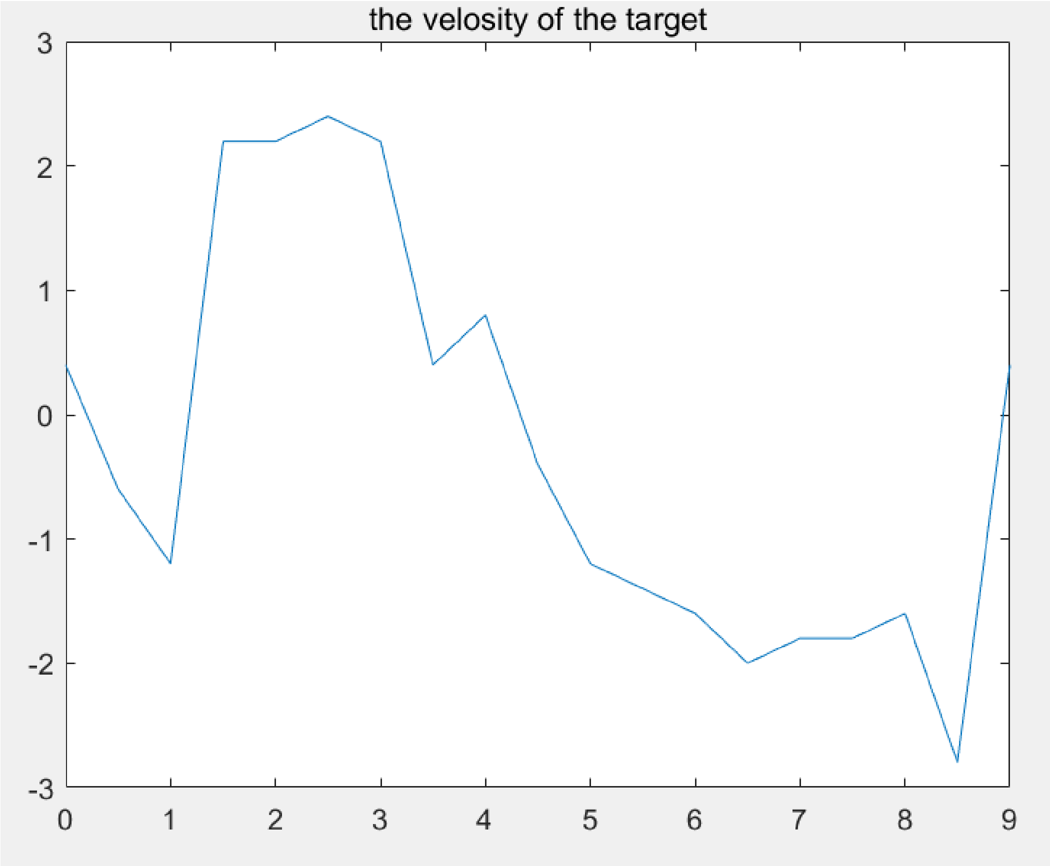
The Doppler-time spectrum of 10s data processed by sliding 0.5s each time with CIT=0.5s as the sliding window.

Conclusion:

1. As can be seen from the figure, the Doppler frequency shift when the Cor function is at its maximum increases first and then decreases with time.
2. When the Doppler shift is positive, it means that the target is approaching the measuring radar, while when the Doppler shift is negative, it means that the target is away from the measuring radar.

$$\text{The target speed}=\frac{\text{The wavelength*the Doppler frequency shift}}{(2*\cos(\beta))}$$

3. According to the formula, the target speed first accelerates to the maximum from the positive direction, then slows down to the maximum from the negative direction, and finally the speed becomes near to zero.



Expand the optimization:

$$Cor(c,d,\mathrm{t}) = \int_{t}^{t+T} y_{\mathrm{sur}}(t+c)y^{*}_{\mathrm{ref}}(t)e^{-j2\pi dt}dt$$

We define ambiguity function, but we notice that length(y_sur) == length(y_ref) == 12500000 is too much data once we use normal algorithm, it costs long time.

Back=y_sur(k+c_i)*y_ref_conj(k)*exp(-1i*2*pi*d_i*k)+Back;

Count_time > 1h

Then we try using dot product algorithm,it speeds up data reading, and using Matlab bottom algorithm optimization at the same time.

out(xxxx)=sum(y_sur_zero.*y_ref_conj_zero.*exp_125_zero);

Count_time = 76.0349

We thought there are algorithms that can speed things up even further, then we use fft algorithm. It reduces complexity to O(NlogN)

cor_n(t,:)=fftshift(fft(ser_zeros.*conj(ref_)));

Count_time = 3.2902

Experience:

We learned to use MATLAB to process the data of passive radar and obtain the speed data of the monitored object.

Through this simulation experiment, we have a further mastery of MATLAB programming.

From the processing of a large number of data, we learned to achieve a significant increase in the speed of operation through the optimization algorithm.