ultrasound$_{a}ssignment10$

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1 Part 1

1.1 a

Assuming the the doppler PRF is 5 kHz

$$v_{nyq} = \frac{cPRF}{4f_0} = \frac{1540m/s \cdot 5 \cdot 10^3 Hz}{4 \cdot 510^6 Hz} = 0.385m/s \tag{1}$$

1.2 b

When increasing the velocity the RF slow time signal will oscillate faster. The wave will be sampled less dense and the wave is observed over a shorter time. The power spectrum widens with the increase of velocity. The reason the the signal becomes less detailed and oscillates faster is because the wave moves past the sampling depth faster. If the velocity is the nyquist velocity will it be impossible to determine if scatters are moving in positive or negative direction. At 0.2 velocity the wave is captured fully and clear. When increasing too 0.5 we loose some details in the wave, but the wave is still captured. In both of these velocities the power spectrum is well defined in the positive region. When increasing to 1.0 velocity, again some of the detailed is lossed and somewaht narrower because of the increased speed. Here we also get leaks in the power spectrum to the negative region. When increasing to 1.5, we almost loose the entire wave, so the wave moves to fast to be captured. Here we also get the peak in the negative region of the power spectrum. This is because of aliasing. From this we can conclude that at the nyquist velocity and above its not possible to determine which direction the wave moves in.

1.3 c

For decreasing the spectral bandwidth we can decrease the pulse bandwidth. To do this we can increase the number of pulse cycles, but this will result in poorer spatial resolution. We can also increase the observation time for the pulse. This will also make the bandwidth smaller.

2 Part 2

2.1 a

This can be expressed as:

$$f_D = f_0 \frac{v}{c} cos(\phi) \tag{2}$$

2.2 b

2.2.1 1

Since $cos(\frac{\pi}{2}) = 0$ will the Doppler shift be 0.

2.2.2 2

Here we again use the formula in (a), but since blood is a moving source we need to multiply by 2. When $\phi = 45°$ the Doppler shift will be:

$$f_D = 2 \cdot 2.5 \cdot 10^6 \frac{1}{1540} cos(\frac{\pi}{4}) \approx 2.3\text{kHz} \tag{3}$$

2.3 c

2.3.1 1

$$\text{PRF} = \frac{1}{\Delta t} \tag{4}$$

To find the maximum distance, d: $d = \frac{0.077}{cos(45°)} = 0.0109m = 10.9cm$

$$\Delta t = \frac{0.109 \cdot 2}{1540} = 0.14ms \tag{5}$$

this gives

$$\text{PRF} = \frac{1}{0.14 \cdot 10^{-3}} = 7142\text{Hz} \tag{6}$$

2.3.2 2

Maximum velocity is:

$$v_{\text{nyq}} = \frac{c \cdot \text{PRF}}{4f_0} = 1.5cos(\frac{\pi}{4}) \tag{7}$$

solving for f_0 gives us:

$$f_0 = \frac{c \cdot \text{PRF}}{4 \cdot 1.5cos(\frac{\pi}{4})} = \frac{1540 \cdot 7142}{4 \cdot 1.5cos(\frac{\pi}{4})} \approx 2.6\text{MHz} \tag{8}$$

2.3.3 3

$$f_D = 2 \cdot 2.6 \cdot 10^6 \frac{1.5}{1540} cos(\frac{\pi}{6}) \approx 4.39\text{kHz} \tag{9}$$

We first have to calculate the radial velocity.

$$v_{rad} = \frac{cf_D}{2 \cdot f_0} = \frac{1540 \cdot 4.39 \cdot 10^3}{2 \cdot 2.6 \cdot 10^6} = 1.3 \tag{10}$$

$$v = \frac{1.3}{cos(\frac{\pi}{6}}) = 1.5m/s \tag{11}$$

2.4 d

2.4.1 1

True. In CW there is no way to determine where along the Doppler line the received signal are recorded/orginate from. Therefor we will not have any spatial resolution, as it receives from every depth simultaneously.

2.4.2 2

True. When the distance increases, will it take longer time for the pulse to travel the full distance back and forth. Therefor you have to wait a longer time before transmitting a new pulse. Then the PRF will decrease. This means that the PRF is inversely proportional with the distance.

2.4.3 3

True. When increasing the transmit frequency will lower the Nyquist velocity. This will improve the velocity resolution as shown in Part 1b.

2.4.4 4

False. Color flow is used for visualization, and the data is only semi quantitative. For high velocity it is necessary to use CW (at least in deep regions).

2.4.5 5

False. Shorter pulse length will give a wider bandwidth in the power spectrum. This makes it harder to distinguish two scatters with different velocity.

3 Part 3

The part 3 result can be seen in the matlab livescript pdf and code. and here.

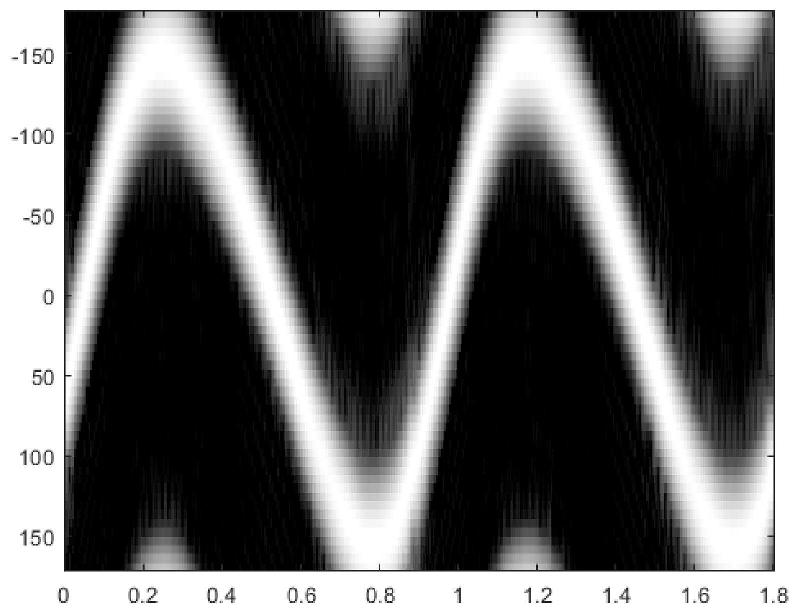

Figure 1: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]

4 Part 4

The part 4 result can be seen in the matlab livescript pdf and code. Here we can see that we get aliasing as a result of the fast motion. For higher magnitudes we can see that the Doppler shift changes sign and wraps around the image. When we stack 3 dopplershift on top of each other we can see what the actual image should look like.

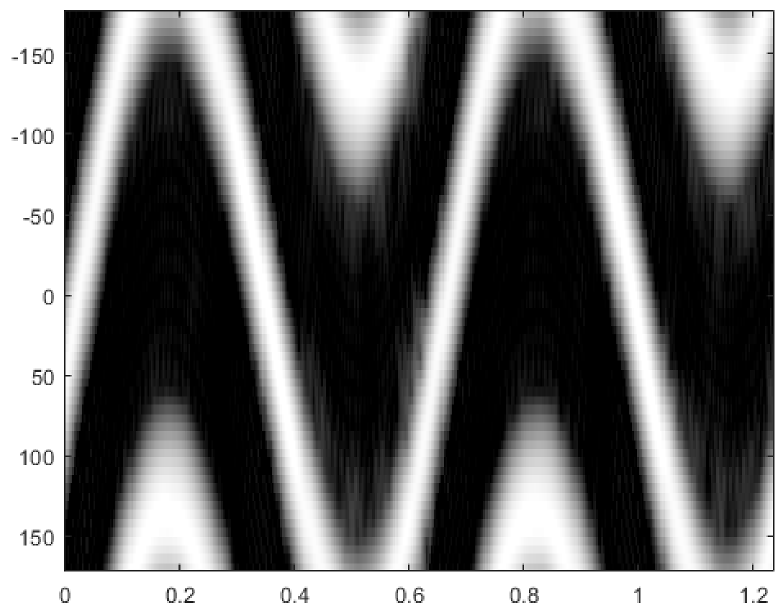

Figure 2: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]

stacked:

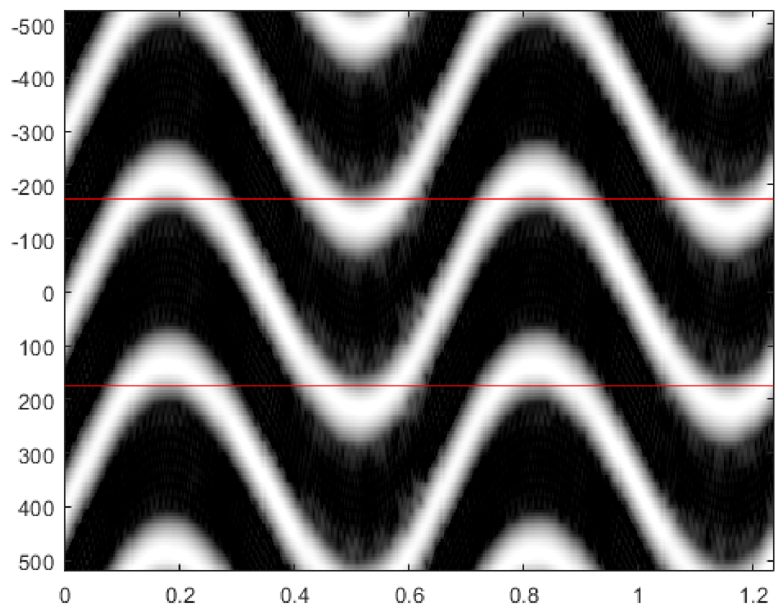

Figure 3: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]

5 Part 5

5.1 1

The image can be seen in the matlab file. The image is similar to the one in slowmotion.mat only weaker and with a strong clutter noise around zero.

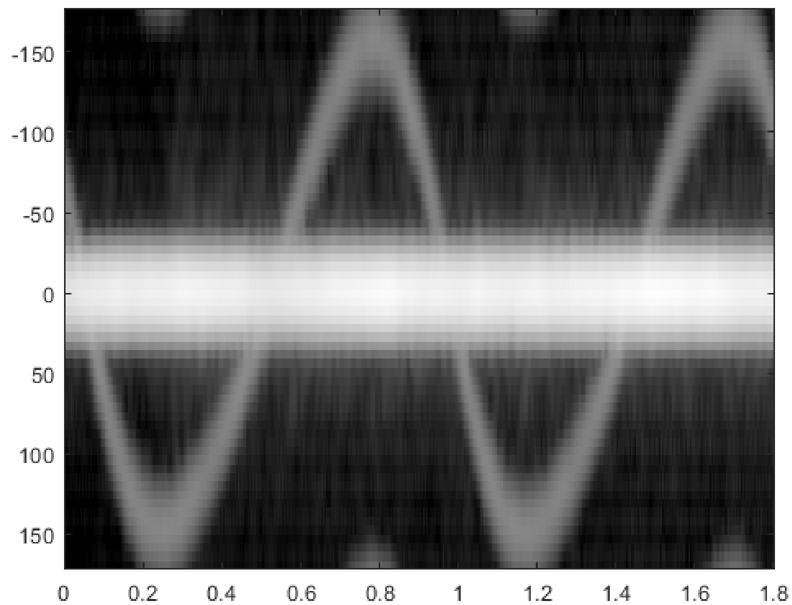

Figure 4: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]

5.2 2

By using a highpass filter with N = 2 (this gave the best result) we can the filtered result. The filter removed the clutter noise but at the cost of some lost data around 0. Tried with both a box filter and a hamming filter, and they very similar result, was difficult to see the difference.

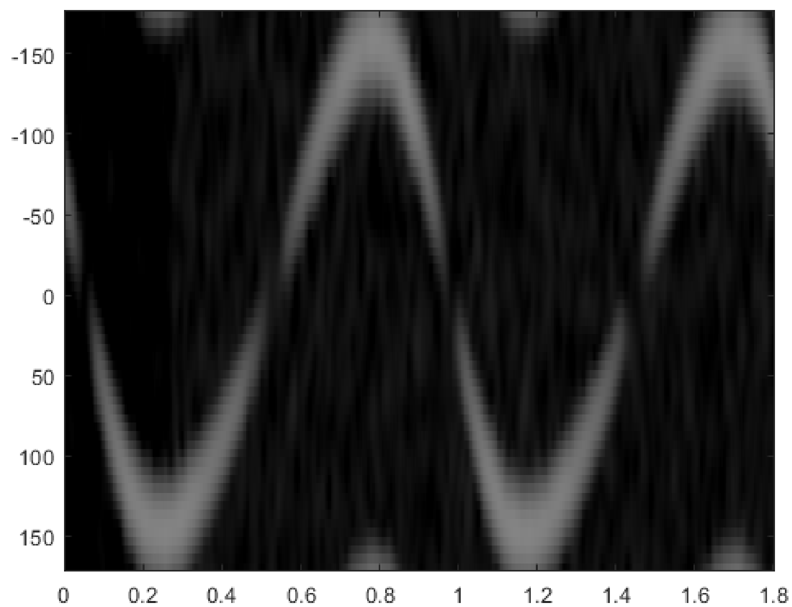

Figure 5: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]. This is with hamming filter

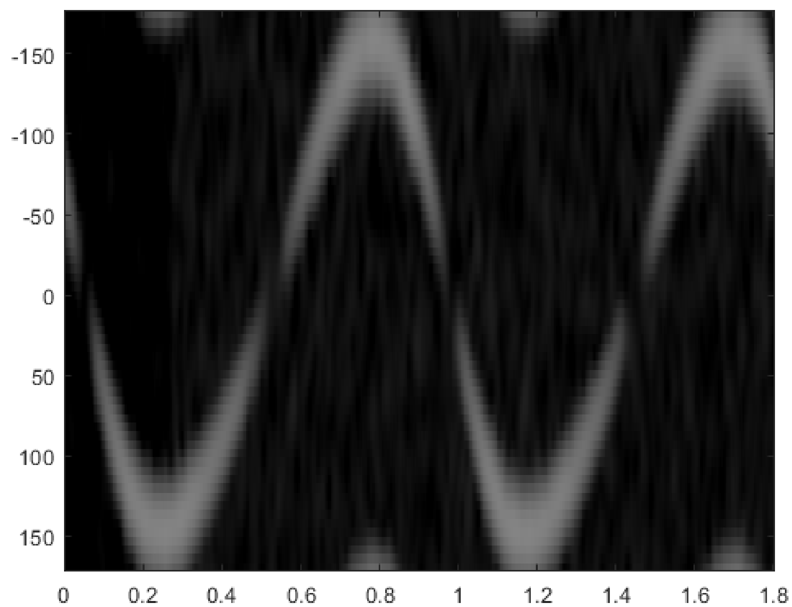

Figure 6: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]. This is with rectangular filter

5.3 3

We can see that we get a good m mode image, but have lost some information.

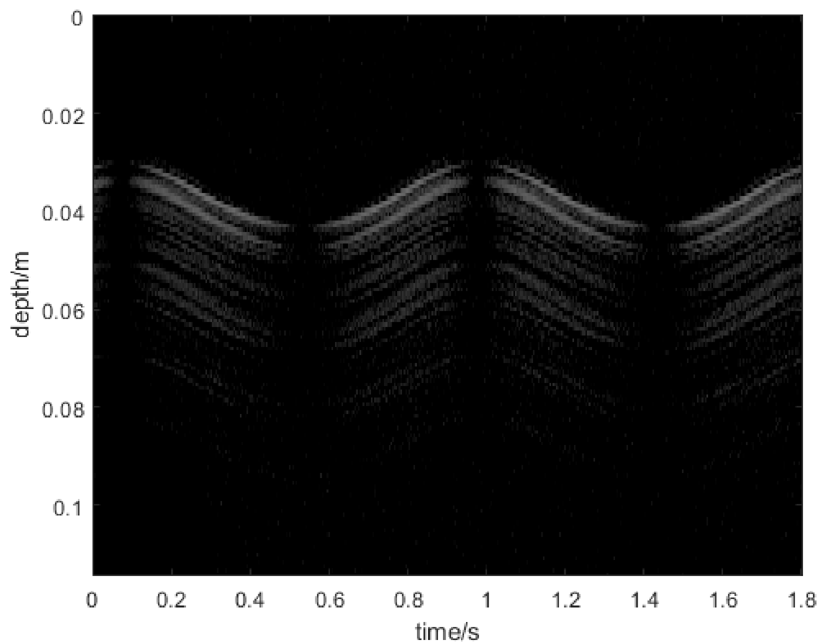

Figure 7: Forgot the axis on the image but y-axis should be depth/m, and x-axis should be time [s]

6 Part 6

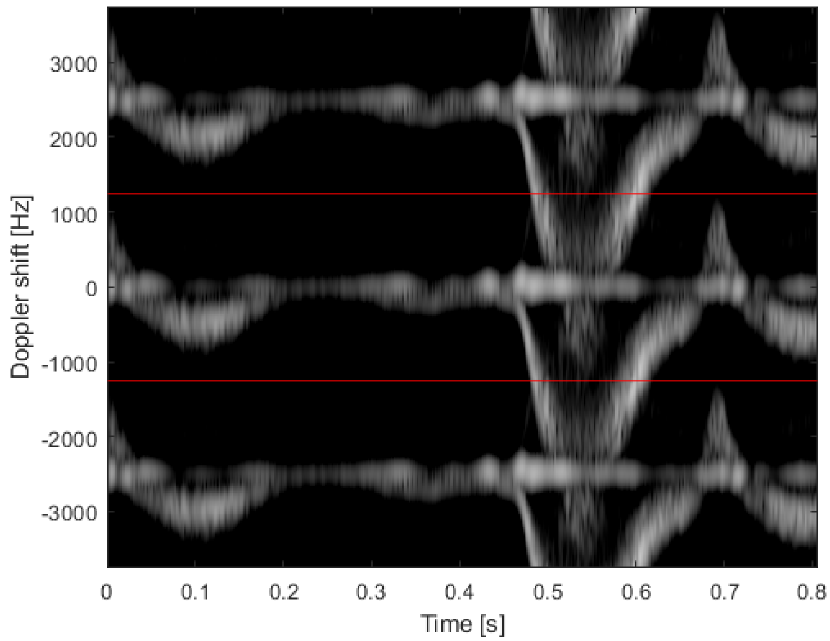

Figure 8: Forgot the axis on the image but y-axis should be doppler shift [Hz], and x-axis should be time [s]. This is with hamming filter

From testing I found that segment of 32 with a hamming filter with N=2 (rectangular gave almost the same) and a dynamic range set too 30 and gain too -60 gave the best result. Can see from the image that the maximum doppler shift is around -3 kHz.

$$v = \frac{1540 \cdot 3 \cdot 10^3}{2 \cdot 2.5 \cdot 10^6} = 0.924\text{m/s} \tag{12}$$

Finds the nyquist limit to be 1.24 kHz, which corresponds to 0.382 m/s. To avoid aliasing then the nyquist velocity needs to be 0.924 m/s. Then the PRF needed to avoid aliasing given by:

$$\text{PRF} = \frac{4 \cdot 2.5 \cdot 10^6 \cdot 0.924}{1540} = 6kHz \tag{13}$$