Principles of Biomedical Ultrasound and Photoacoustics
hw04-1: Single Element Synthetic Aperture Focusing

Due on Thursday, Nov 16, 2017

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1 Introduction

In this homework, we will simulate phased array system beam forming.

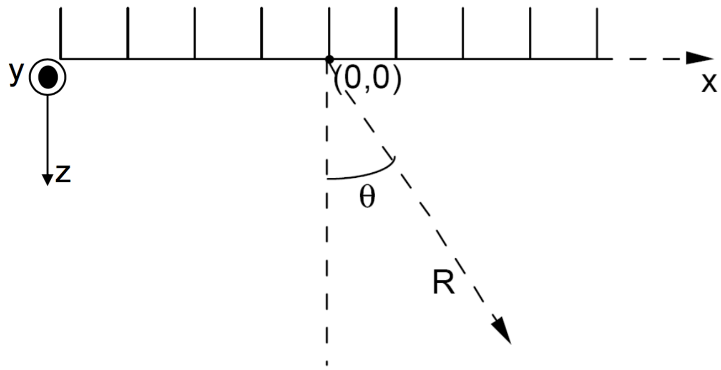

Figure 1: Phase array system

To create the channel data, we can follow the steps below.

1. The transmitter (i.e., each array element) is a perfect point source
2. The receiver (i.e., each array element) is a perfect point receiver
3. There is no attenuation. That is, the received signal does not need to be gain compensated.
4. The sound speed is 1.5 mm/us or 1500 m/s
5. The complete channel data are collected with consecutive single element transmitting and receiving.
6. The position of the 3 point targets in (x,y,z): (-5, 0, 10), (0, 0, 20), (15,0,30) in mm.
7. The initial sampling rate (i.e., fs) is set to 64*fc to emulate analog channel data
8. Perform decimation on emulated analog channel data so that the resultant sampling rate (i.e., fs) is 4*fc on sampled channel data
9. Make wavefield plots of the analog and sampled data (i.e., image of channel data). The gray scale is setup so that zero pressure is midgray, positive pressure is white, and negative pressure is black.

2 Problems

Implement RF and baseband dynamic receive beamformer to make a 120-degree sector scan image from the sampled channel data.

2.a Define beam spacing and the number of total beams

The beam space is uniformly divided in sine space.

$$\Delta \sin\theta = \frac{\lambda}{2D} = 0.0156$$

in mm. The number of beams is

$$\frac{\sqrt{3}}{\Delta \sin\theta} = 111$$

2.b RF and baseband beamforming

Now we show beamforming of RF and Baseband as shown in Figure [2 3].

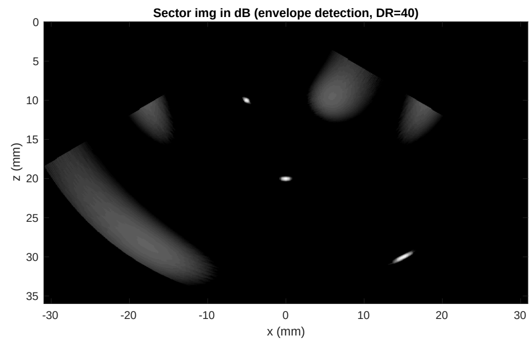

Figure 2: Sector image (RF)

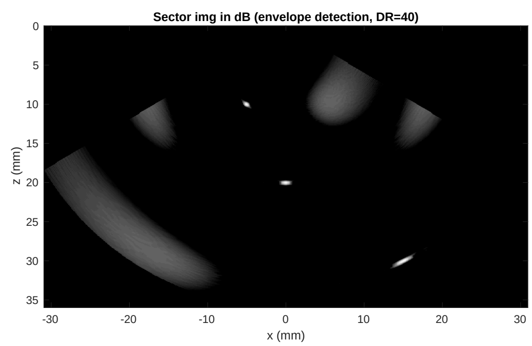

Figure 3: Sector image (Baseband)

Figure 4 show the original spectrum of center scanline for RF beamforming.

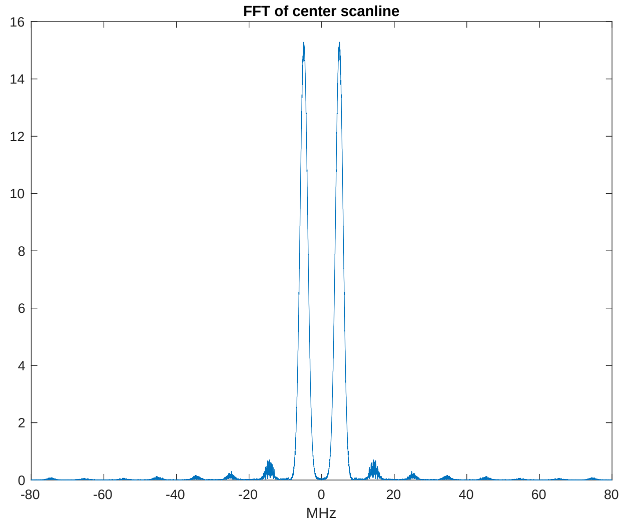

Figure 4: FFT (origin)

Now we apply demodulation with the following formula

$$BBbeam = BBbeam * \exp^{-2\pi * fc * t * j}$$

And the spectrum will shift -fc as shown in Figure 5

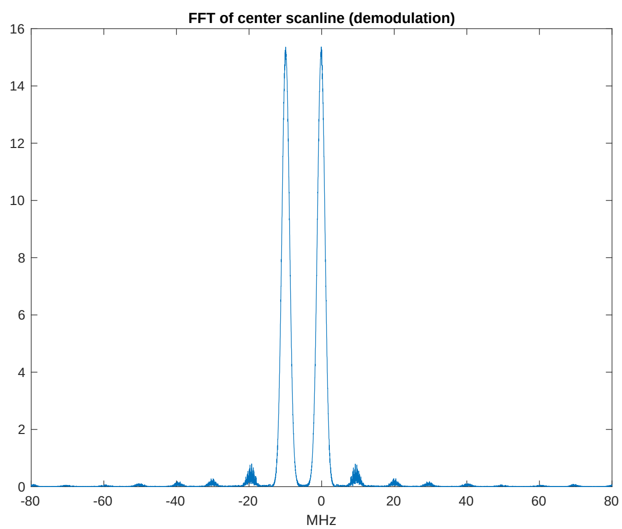

Figure 5: FFT (demodulation)

Now we apply a low pass filter with cutoff frquency fc (Figure 6) to preserve the main lobe only (Figure 7)

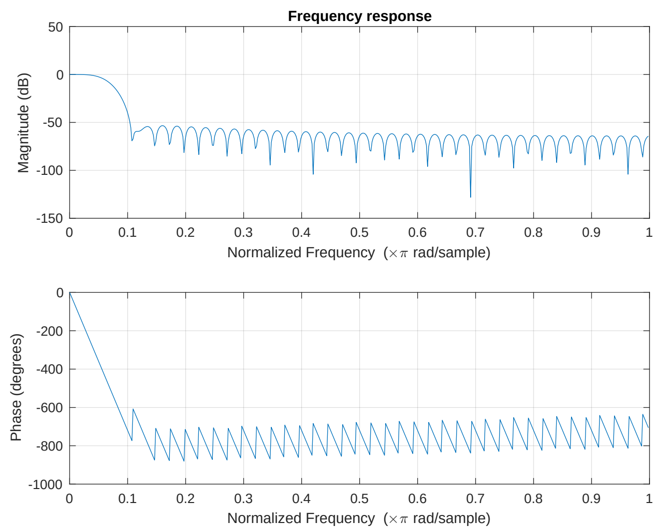

Figure 6: LPF frequency response

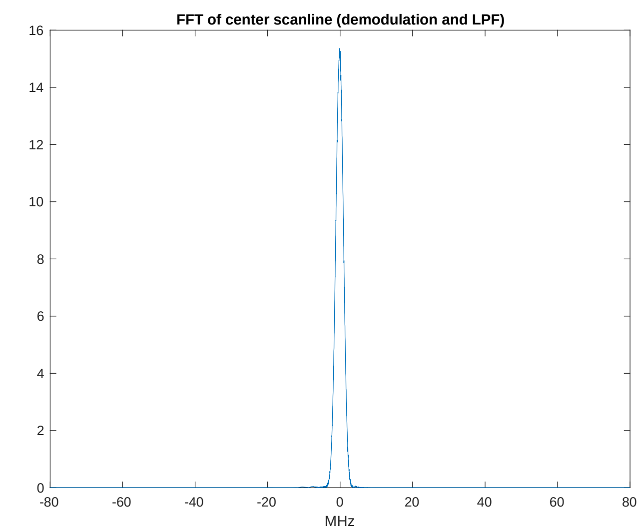

Figure 7: FFT (demodulation and LPF)

Now we finish all steps of baseband demodulation.