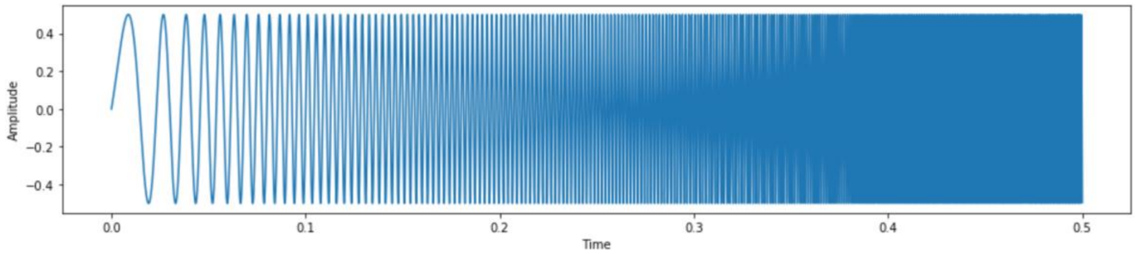
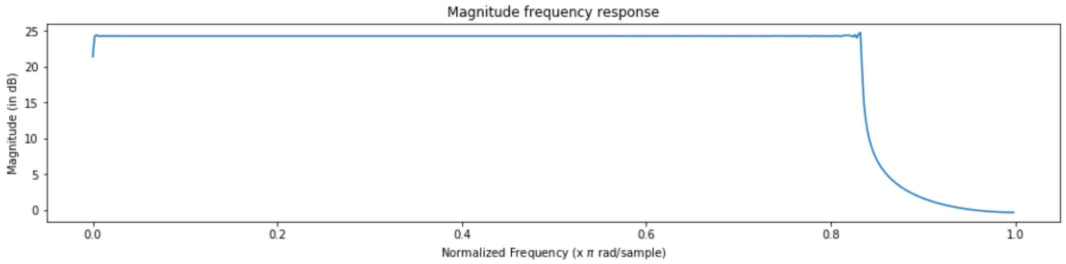
Part I Task I:

The simultaneous frequency started from 20 Hz and it kept increasing until it reached 20khz.

In time spectrum we have:



In frequency spectrum we have:

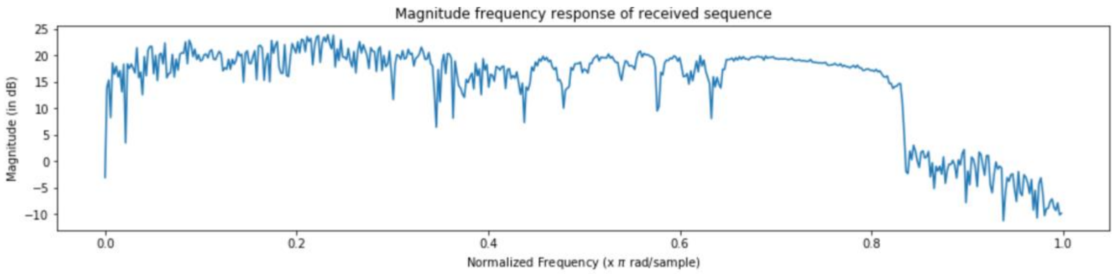


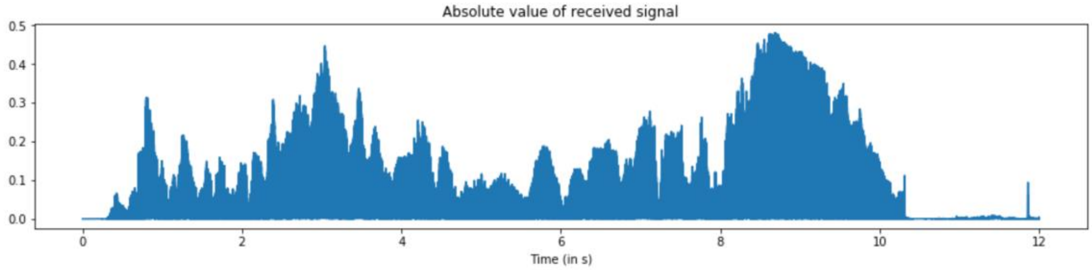
Explain why the chirp is an appropriate signal to measure the magnitude frequency response of a system.

That is because the signal keep constant from 20hz to 20khz (from 0.0 to around 0.85π), i.e. it is an approximately all pass filter. Also, it is pretty easy to get the value of magnitude frequency form input formula. Furthermore, it is pretty easy to produce.

Part I Task II: Playing and Recording the Chirp

The pitch of the audio sound was getting higher until it could not be captured by human ear.





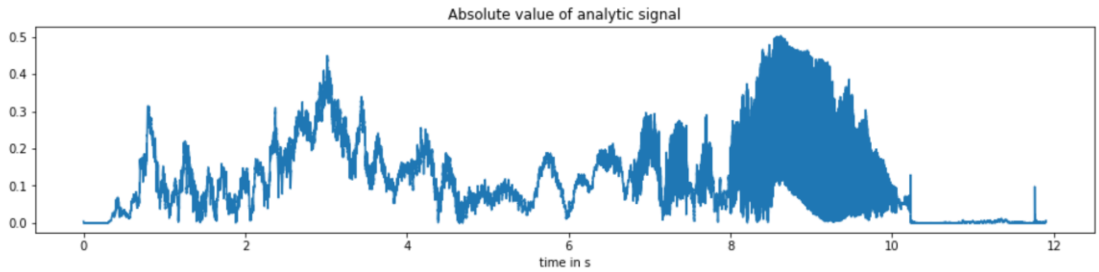
Comment on the results you got. In addition, what is the implicit assumption we are making in order to claim that the result is a frequency response? (HINT: consider the case when the chirp was very short)

The sound approximately keep constant from 0.0 until 0.85π and it fall down to -ve db rapidly after 0.85π.

Our assumption is that the there exists a cutoff frequency around 0.85π and it is. We also assume the function will keep constant. The result is what I was expected.

Part I, Task III: Envelope detection with Hilbert transform

I got an approximate envelop of the receiving signal after Hilbert transform

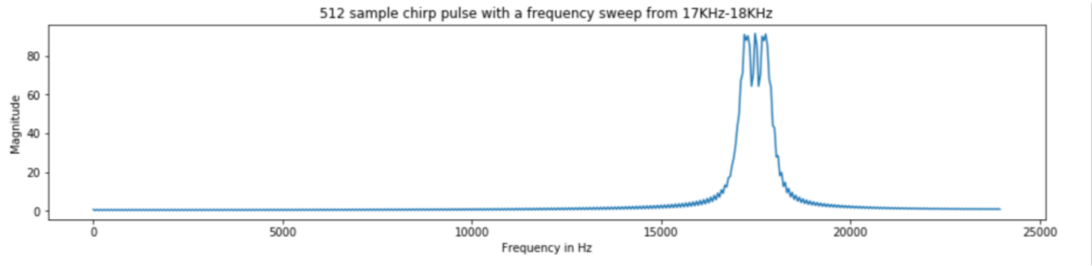


As mentioned in the question description, the envelop of signal is not ideal.

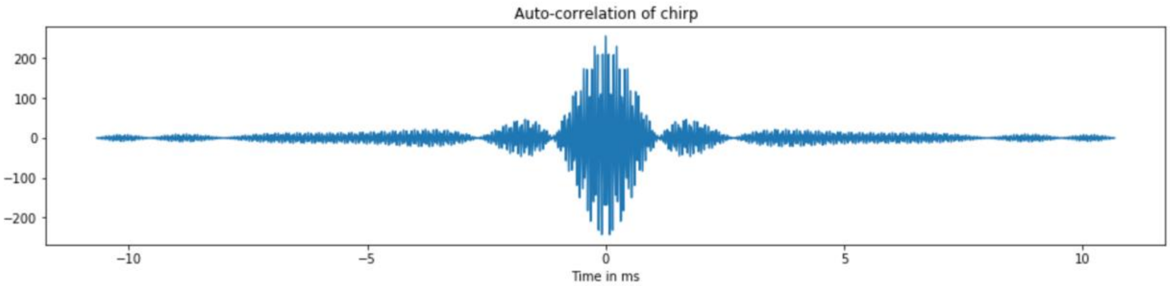
Part I, Task IV: Auto-correlation Properties of the Chirp:¶

Now we generate a 512 sample chirp pulse with a frequency sweep from 17KHz-18KHz and 48k sampling rate

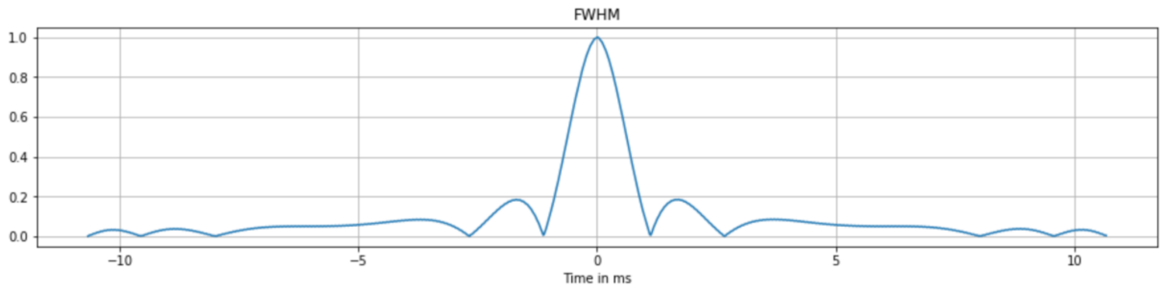
In frequency domain:



The auto-correlation of signal in time domain:



We now measure the full-width at half max (FWHM) of the main lobe of the autocorrelation:



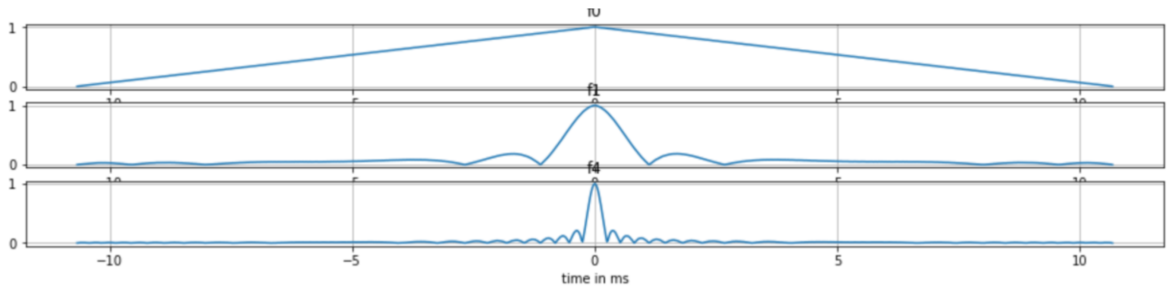
The half of the maximum is around 0.623 ms. So FWHM = 1.246 ms. The ratio is n/fs/FWHN = 8.56.

I repeat the experiment with

1. A constant frequency of 17000Hz, 512 samples in length. Denote as auto_chirp_0
2. A chirp with a frequency sweep from 16500Hz - 17500Hz (1KHz Bandwidth), 512 in length. Denote as auto_chirp_1

3. A chirp with a frequency sweep from 15000Hz - 19000Hz (4KHz Bandwidth), 512 in length. Denote as auto_chirp_2 (In my Jupiter notebook file, my teammate denote it as Denote as auto_chirp_4)

My teammate plot auto_chirp_0, auto_chirp_1, auto_chirp_2 respectively.



Pulse Compression:

chirp_0 = 1,chirp_1 = 8.8, chirp_2 (or chirp_4 in jupyter notebook) = 35.8

What is the approximate bandwidth of the pure frequency pulse and what is the bandwidth of the chirp pulses?

The bandwidth of pure tone is 0

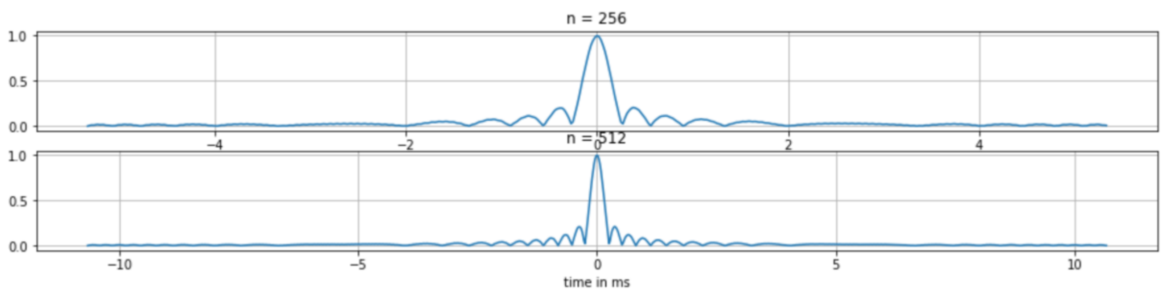
The bandwidth of chirp signal 1 is 1000Hz.

The bandwidth of chirp signal 2 is 4000Hz.

The bandwidth will increase with the increasing pulse compression.

What is the maximum autocorrelation for each pulse?

chirp_0 =255.45886883384938
chirp_1 =255.43518472749108
chirp_2 =255.34313163945103



Compare the size of the main lobe (full width at half max) to the previous case of 15000Hz - 19000Hz, 512 in length.

The increase bandwidth make the FWHM narrower

Also, the pulse compression is higher if the bandwidth increase.

Compare the maximum autocorrelation between two graphs.

max autocorrelation:

When n=256:

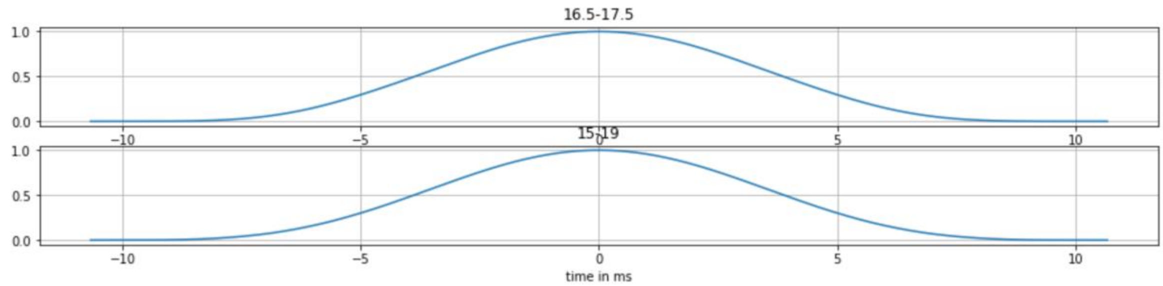
maximum autocorrelation=127.90772448543606

when n=512:

maximum autocorrelation=255.34313163945103

Dealing with sidelobes¶

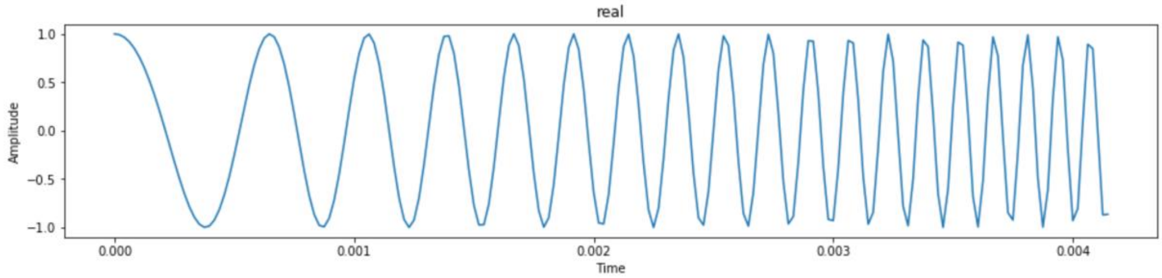
normalized autocorrelations:



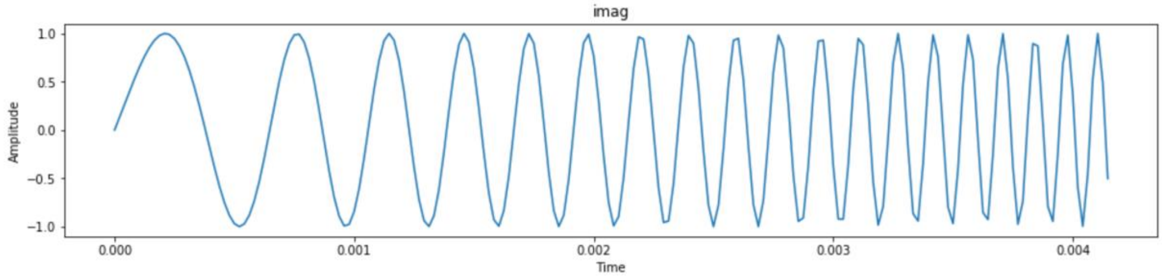
If we double the width of the main lobe, the maximum autocerrleation would get reduced.

Part II, Task I: Generating Chirp Pulses
Generate a signal with Npulse = 200, f0=1000, f1 = 8000, fs = 48000

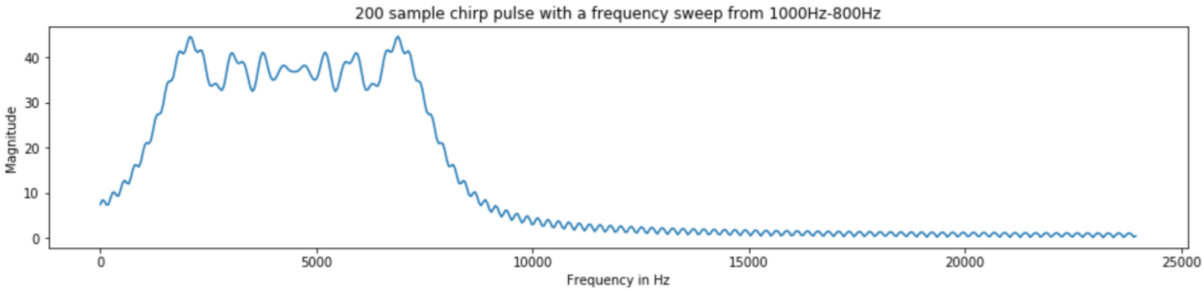
Time domain:



<Figure size 432x288 with 0 Axes>



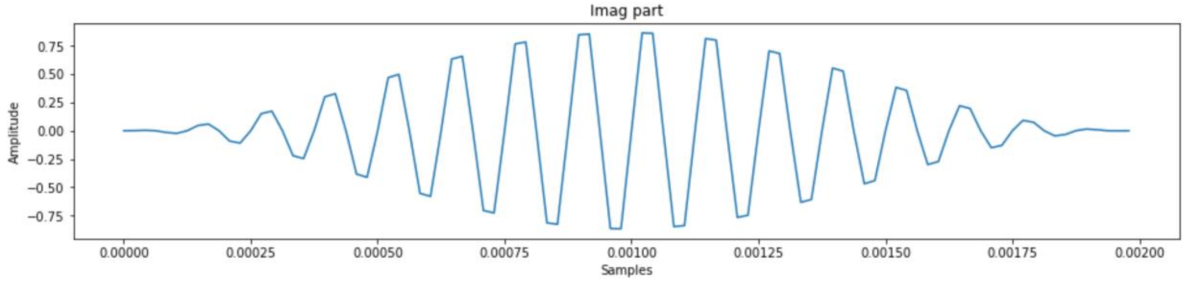
Frequency domain:

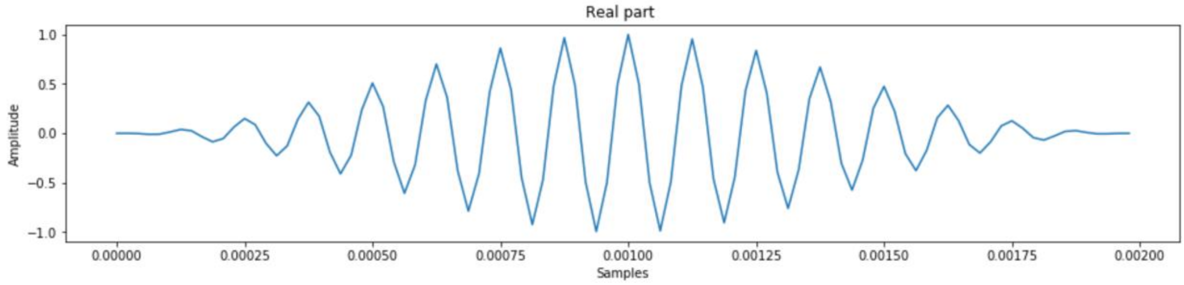


The **Generate Pulse Trains** function has already created by lecturer.

Part II, Task II: Echos in with Chirp pulse train

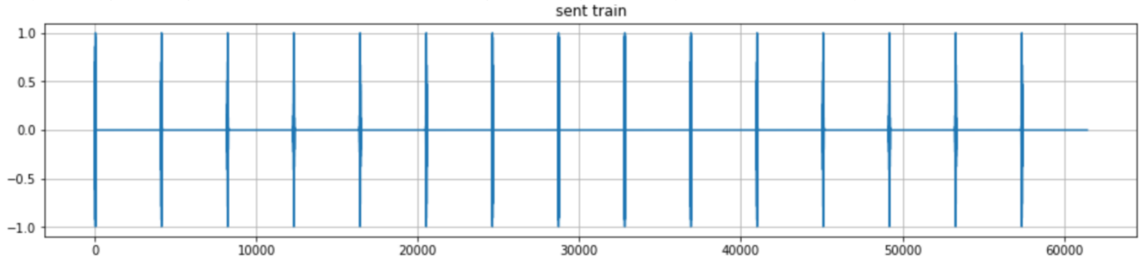
Generate a f0=f1=8KHz, Npulse=96 pulse with fs=48000. Window the pulse with a hanning window:



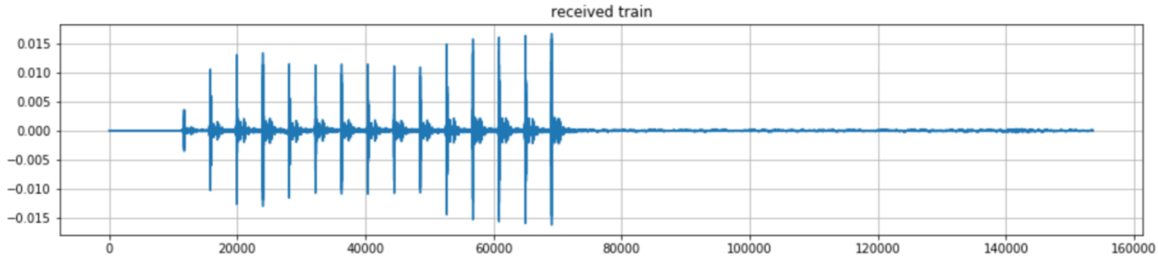


I was able to hear that sound.

Zero-padding the signal such that make the length of segment equals to 4096. Repeat 15 times.

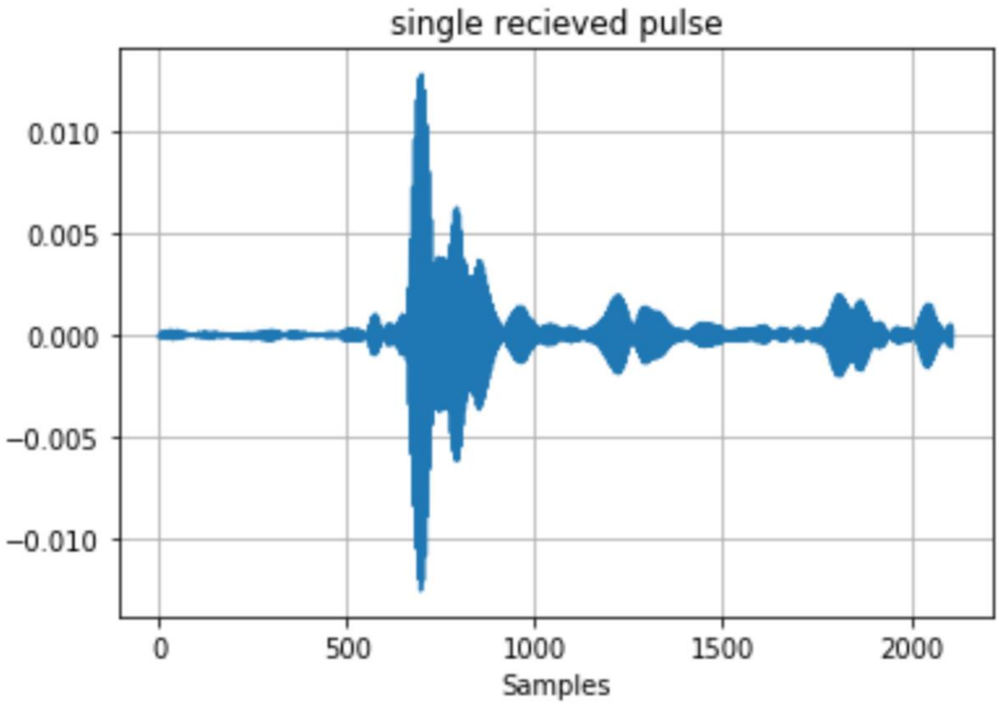


<Figure size 432x288 with 0 Axes>



I heard 15 sounds. The echoes observed(those small judders)

I extracted a single pulse from the received pulse train

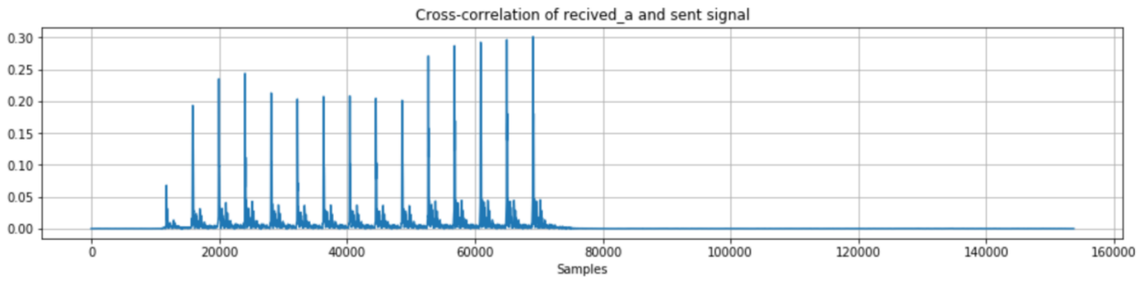


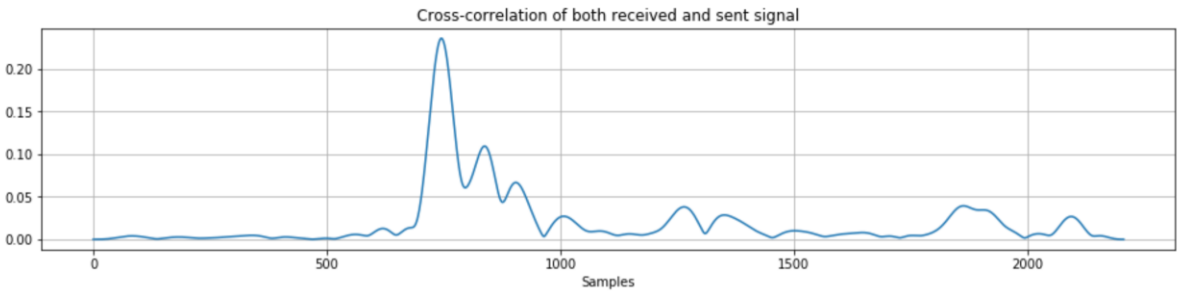
We could observe the existence of echoes. Note that I was using

$$rcv\_pulse = rcv[idx - 2 * Npulse{:}\, idx + Npulse * 20]$$

In this case, $\mathrm{idx} = 4096 * 5 + 3000$.

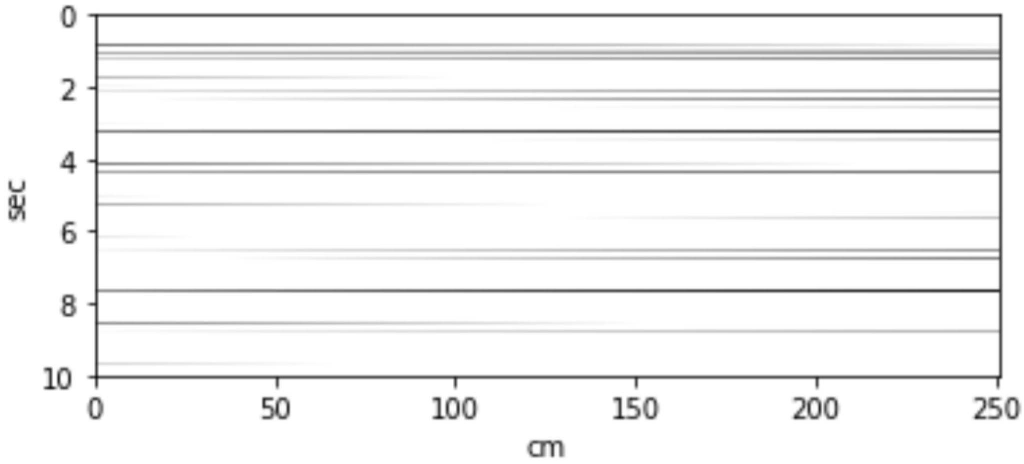
Matched Filtering





We detected the echoes because we have we have sidelobes after the mainlobe around idx +750 samples.

A sonar (almost)



I am not sure about the last bit.

Contribution:

I team up with 3 students in Team 5, They are Jade Zhao, Serge Naufal and Arthur Wang

I have done some parts of Part I.

Jade Zhao and me finish part II together.