Antenna Array Processing

HW3

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```
clear; clc; close all;
```

Q1:

۱- لطفا فایل های متلب مرتبط با ویدیوی روز ۳ شنبه ۳ آبان را خط به خط چک کنید تا مطمئن بشید اونها رو کامل درک کردید. احتیاجی نیست برای این قسمت گزارشی بنویسید.

An MLX file is prepared to show that codes are checked line by line and the result is depicted in each section.

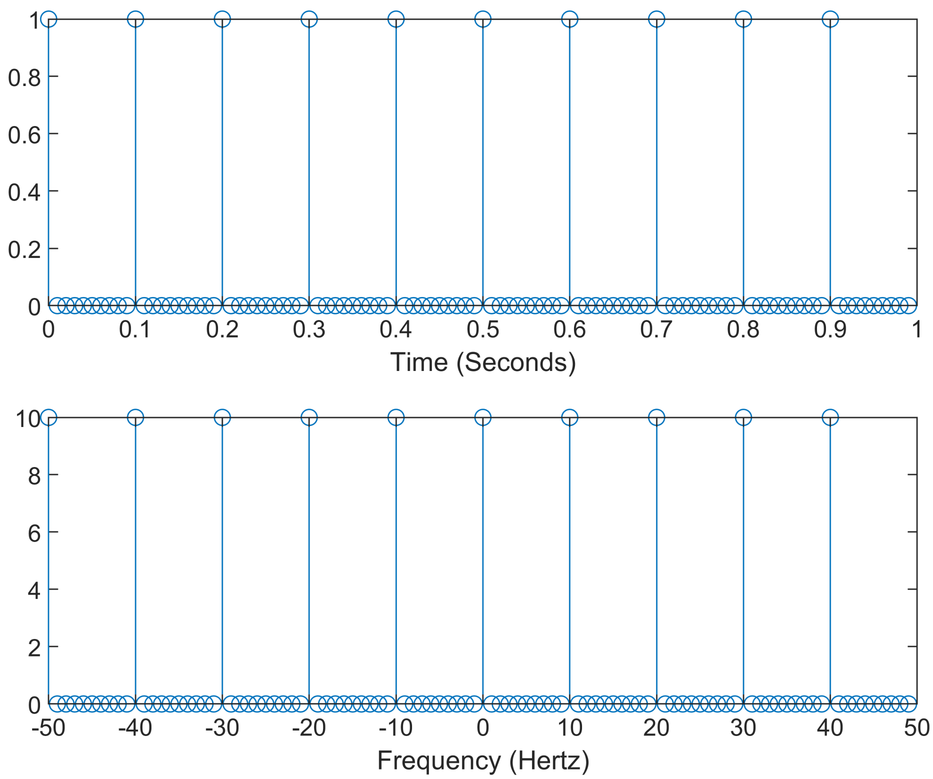
Q2:

۲- فرض کنید range اهداف به جای ۴۵۰۰ و ۷۵۰۰ کیلومتر، به ترتیب ۵۰۰۰ و ۸۰۰۰ کیلومتر باشد. به سایر پارمترها دست نزنید و نویز را هم صفر در نظر بگیرید. تصویر خروجی ماتریس رنج داپلر را رسم کنید. چرا در نقاطی که پیک دیده می شود، پیک پهنی داریم؟

```
% We have to change Ranges of the target and consider a noise-free
% enviroment ---> using given Code and changing some parameters;

% Signals are considered to be in Low Frequency Band
ts =  1e-2; % --> 10 ms
fs=1/ts; % sampling rate --> 100Hz
C=300e6; % light speed

tau_num=1;  % --> Consider a single sample on the signal
tau=tau_num*ts; % --> the signal length would be equal to number of samples multiplied by lengt

PRI=1e-1;
PRI_num=round(PRI/ts); % --> number of sqaured pulses in signal

PRF=1/PRI;

Trecording=1;   % --> Recording time at the receiver!

deltaf=1/Trecording; % Frequency Resolution

pulse_num=round(Trecording/PRI); % Number of pulse in recording time
sample_num=round(Trecording/ts);
```

```
t=0:ts:Trecording-ts; % Time Vector
freq=-fs/2:deltaf:fs/2-deltaf; % Frequency Vector
```

```
% Create Our Signal : The one Pulse:
SL_PRI=[ones(1,tau_num) zeros(1,PRI_num-tau_num)]; % single pulse in the interval of sending ar
sl=repmat(SL_PRI,1,pulse_num); % Repeated pulse for each PRI in Trecording

figure(1)
subplot(2,1,1)
stem(t,sl) % The Signal itself --> Pulse Train
xlabel('Time (Seconds)')

subplot(2,1,2)
slf=fftshift(fft(sl)); % shifted fft signal --> Fourier transformation --> I expect to see the
stem(freq,abs(slf)) % Frequency Domain
xlabel('Frequency (Hertz)')
```



Target-1:

```
delay_Target1=round(5/1.5)*ts;
R_Target1=C/2*delay_Target1;  %R=5000 KM
fd_Target1=-2*deltaf;    % fd= -2 Hz
beta_Target1=0.2; % Attenuation Factor!
% Receiving signal:
% y =  b*dopplershift*sl(t-td)
```

```
y_Target1=beta_Target1*exp(1j*2*pi*fd_Target1*t).*circshift(sl,delay_Target1/ts);  % Shifting t
```

Target-2:

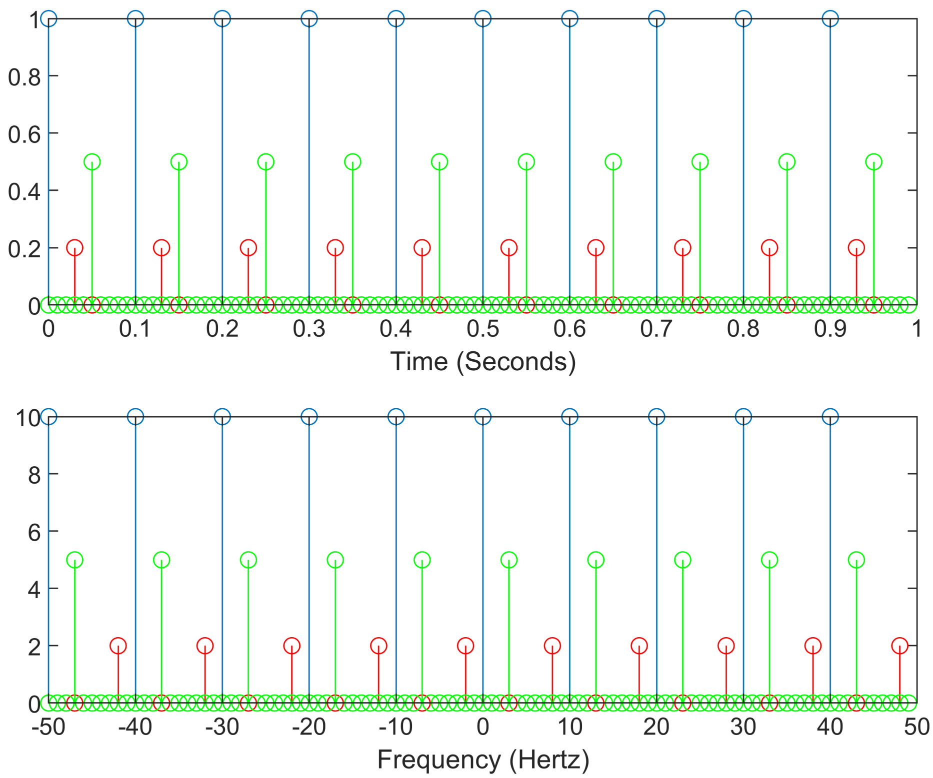
```
delay_Target2=round(8/1.5)*ts;
R_Target2=C/2*delay_Target2; % R=8000 KM
fd_Target2=3*deltaf;    % fd=3 Hz
beta_Target2=0.5;
% Receiving signal:
% y =  b*dopplershift*sl(t-td)
y_Target2=beta_Target2*exp(1j*2*pi*fd_Target2*t).*circshift(sl,delay_Target2/ts);  % Shifting t
```

Let's see the time domain signals:

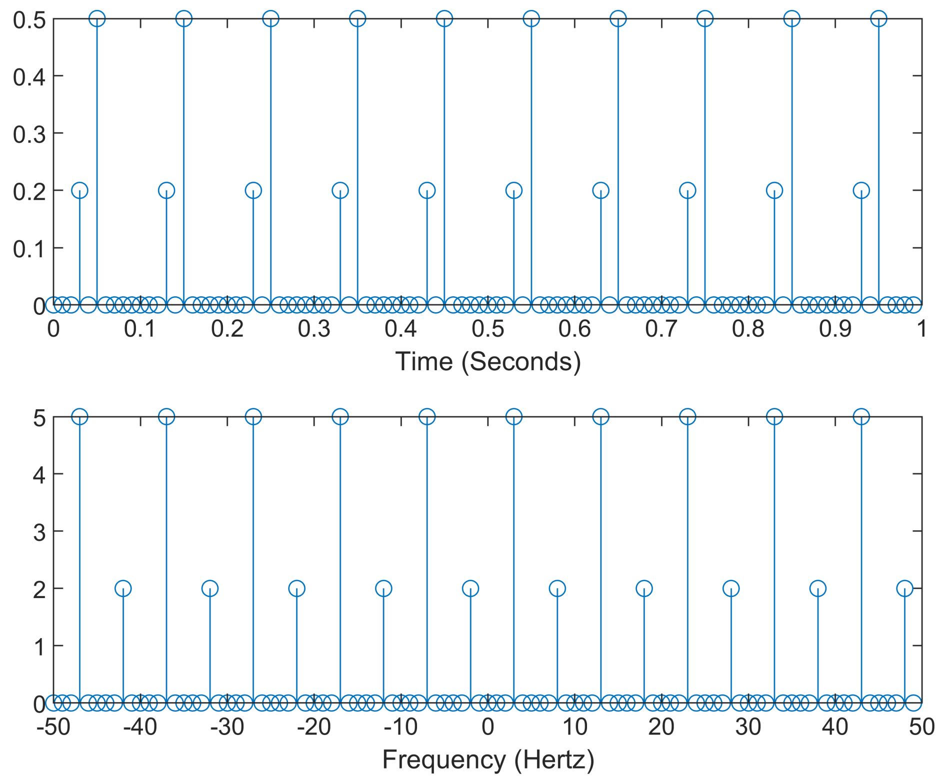
```
figure(2)
subplot(2,1,1)
stem(t,sl)
hold on
stem(t,abs(y_Target1),'r')
stem(t,abs(y_Target2),'g')
xlabel('Time (Seconds)')
```

Also, the Frequency domain of received signals:

```

subplot(2,1,2)
yf_Target1=fftshift(fft(y_Target1));
yf_Target2=fftshift(fft(y_Target2));
stem(freq,abs(slf))
hold on
stem(freq,abs(yf_Target1),'r')
stem(freq,abs(yf_Target2),'g')
xlabel('Frequency (Hertz)')
```

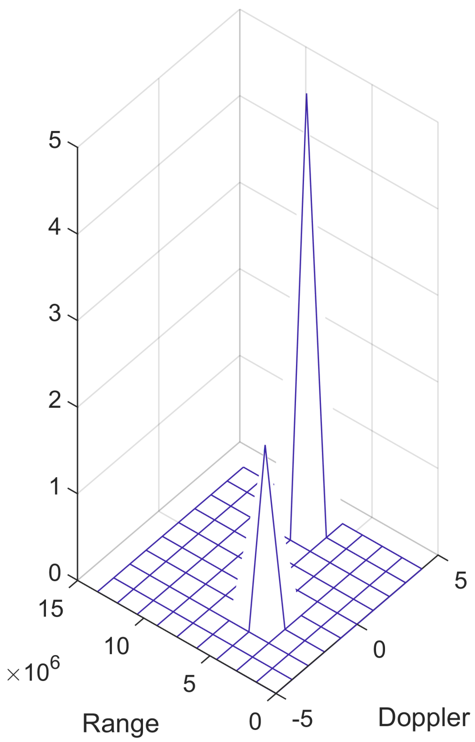


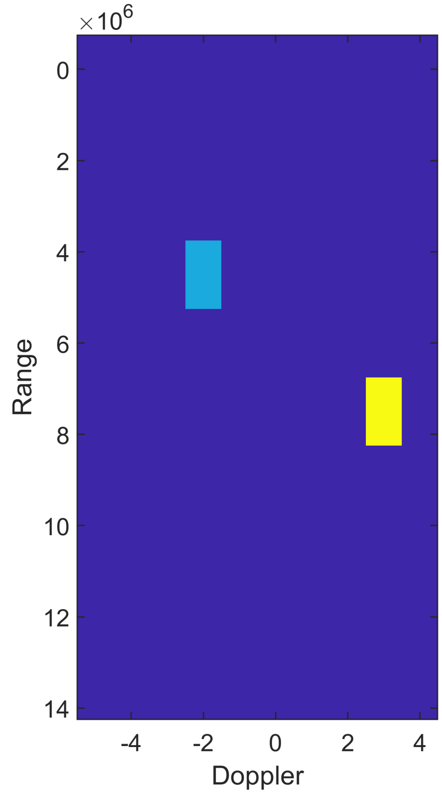

```
figure(3)
y=y_Target1+y_Target2;
yf=fftshift(fft(y));


subplot(2,1,1)
stem(t,abs(y)) % Total signal Time domain
xlabel('Time (Seconds)')

subplot(2,1,2)
stem(freq,abs(yf)) % Total signal Frequency domain
xlabel('Frequency (Hertz)')
```



Range Doppler Processing:

```
yff=circshift(yf,PRF/2/deltaf); % Shifting the Frequency domain so that the 0 doppler carrier w
yf_reshape=reshape(yff,PRF/deltaf,sample_num*deltaf/PRF).'; % Now starting from -PRF/2, take PR
 % Creating the conjugate of the signal to multiply to yf
SL_PRIf=fftshift(fft(SL_PRI)).';
SL_PRIff=circshift(SL_PRIf,PRF/2/deltaf);

BASE=repmat(conj(SL_PRIff),1,PRF/deltaf); % Conjugate of Base signal to multiply to yf
COEFICIENTS=ifft(yf_reshape.*BASE); % Each Column of yf is multiplied to each column of Base si

figure(4)
subplot(1,2,1)
RANGE=C/2*(0:tau:PRI-tau);
DOPPLER=-PRF/2:deltaf:PRF/2-deltaf;
mesh(DOPPLER,RANGE,(abs(COEFICIENTS)))
ylabel('Range')
xlabel('Doppler')

subplot(1,2,2)
imagesc(DOPPLER,RANGE,(abs(COEFICIENTS)))
ylabel('Range')
xlabel('Doppler')
```





Q3:

۳- فرض کنید doppler اهداف به جای 2- و 3 هرتز، به ترتیب 1.5- و 2.7 هرتز باشد. به سایر پارمترها دست نزنید و نویز را هم صفر در نظر بگیرید. تصویر خروجی ماتریس رنج داپلر را رسم کنید. چرا در نقاطی که پیک دیده می شود، پیک پهنی داریم؟

Target-1:

```
delay_Target1=round(5/1.5)*ts;
R_Target1=C/2*delay_Target1;  %R=4500 KM
fd_Target1=-1.5*deltaf;    % fd= -2 Hz
beta_Target1=0.2; % Attenuation Factor!
% Receiving signal:
% y =  b*dopplershift*sl(t-td)
y_Target1=beta_Target1*exp(1j*2*pi*fd_Target1*t).*circshift(sl,delay_Target1/ts);  % Shifting t
```

Target-2:

```
delay_Target2=round(8/1.5)*ts;
R_Target2=C/2*delay_Target2; % R=7500 KM
fd_Target2=2.7*deltaf;    % fd=3 Hz
beta_Target2=0.5;
% Receiving signal:
```

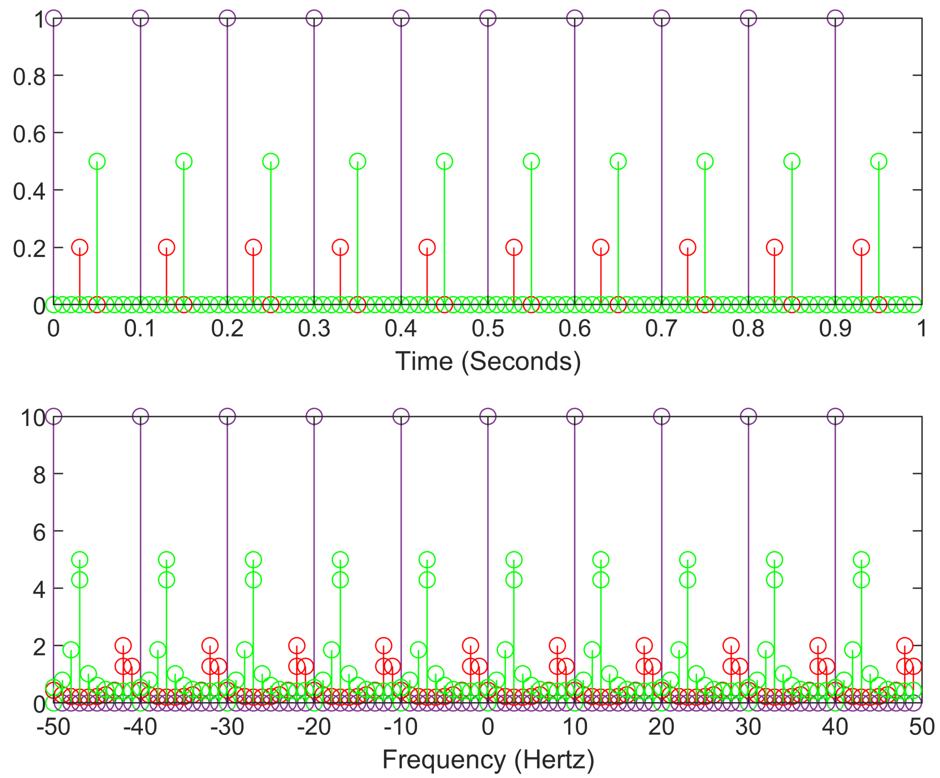
```
% y =  b*dopplershift*sl(t-td)
y_Target2=beta_Target2*exp(1j*2*pi*fd_Target2*t).*circshift(sl,delay_Target2/ts);  % Shifting t
```

Let's see the time domain signals:

```
figure(2)
subplot(2,1,1)
stem(t,sl)
hold on
stem(t,abs(y_Target1),'r')
stem(t,abs(y_Target2),'g')
xlabel('Time (Seconds)')
```

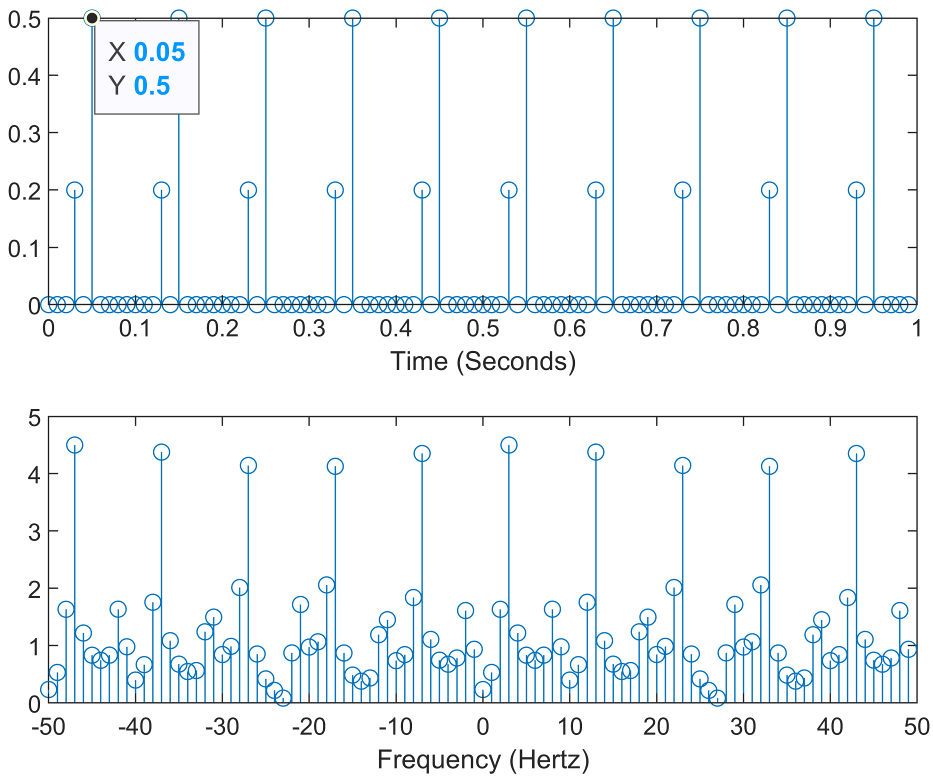
Also, the Frequency domain of received signals:

```

subplot(2,1,2)
yf_Target1=fftshift(fft(y_Target1));
yf_Target2=fftshift(fft(y_Target2));
stem(freq,abs(slf))
hold on
stem(freq,abs(yf_Target1),'r')
stem(freq,abs(yf_Target2),'g')
xlabel('Frequency (Hertz)')
```



We can detect the glitch/ disorder in frequency domain where we have nearly 3 peaks in 3 adjacent frequency bins! --> This is due to frequency resolution.

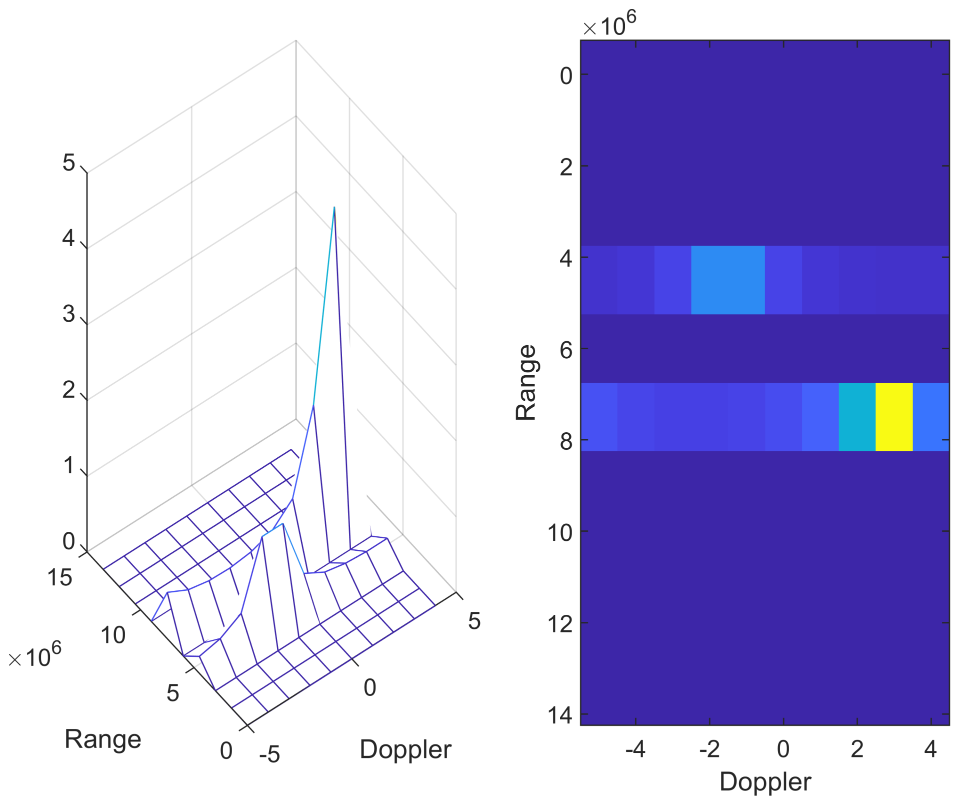
```
figure(3)
y=y_Target1+y_Target2;
yf=fftshift(fft(y));


subplot(2,1,1)
stem(t,abs(y)) % Total signal Time domain
xlabel('Time (Seconds)')

subplot(2,1,2)
stem(freq,abs(yf)) % Total signal Frequency domain
xlabel('Frequency (Hertz)')
```



Received signal is the summation/superposition of both targets! ===> in Time domain we can see targets are seperated with 0.2 and 0.5 amplitude and different positions at 0.5 and 0.3 indicating 0.5/0.1 =5 --> R = c/2 * 5*ts = 7500 Km ; 0.3/0.1 =3 --> R = c/2 * 3*ts = 4500 Km

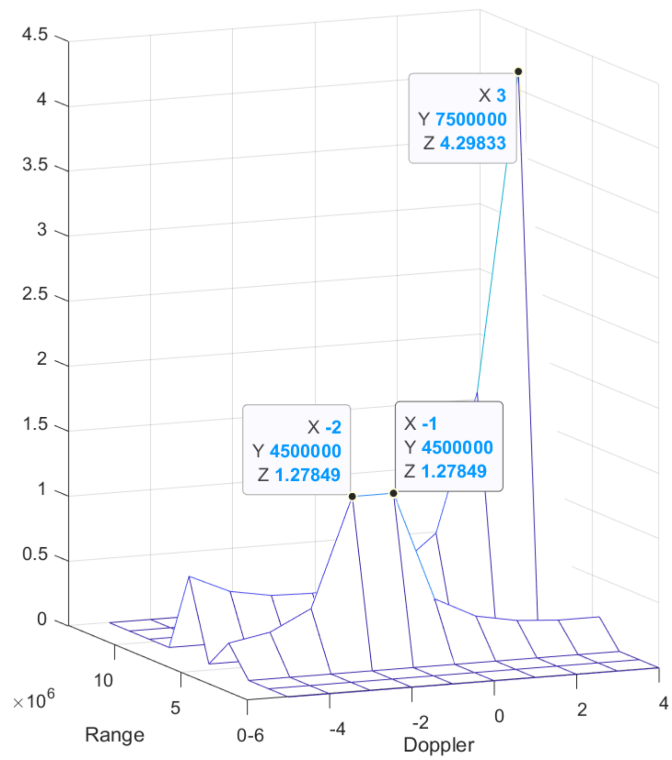
```
yff=circshift(yf,PRF/2/deltaf); % Shifting the Frequency domain so that the 0 doppler carrier
yf_reshape=reshape(yff,PRF/deltaf,sample_num*deltaf/PRF).'; % Now starting from -PRF/2, take
 % Creating the conjugate of the signal to multiply to yf
SL_PRIf=fftshift(fft(SL_PRI)).';
```

```
SL_PRIff=circshift(SL_PRIf,PRF/2/deltaf);

BASE=repmat(conj(SL_PRIff),1,PRF/deltaf); % Conjugate of Base signal to multiply to yf
COEFICIENTS=ifft(yf_reshape.*BASE); % Each Column of yf is multiplied to each column of Base si

figure(4)
subplot(1,2,1)
RANGE=C/2*(0:tau:PRI-tau);
DOPPLER=-PRF/2:deltaf:PRF/2-deltaf;
mesh(DOPPLER,RANGE,(abs(COEFICIENTS)))
ylabel('Range')
xlabel('Doppler')

subplot(1,2,2)
imagesc(DOPPLER,RANGE,(abs(COEFICIENTS)))
ylabel('Range')
xlabel('Doppler')
```



Above, we can see that due to the fact that 2.7 and 1.5 are not integer coefficient of delta_f (Frequency resolution) --> They are mapped into orthonormal basis and the result is that 2.7 is mapped to 2 , 3 Hz with 3 being the major power carrier and -1.5 is mapped to -2 , -1 Hz with both being equally distanced. --> The fact is when you are estimating the doppler, you cannot detect 2.7 Hz and what you detect is 3 Hz due to frequency resolution...

Also, when you have 2 equally spaced inetegr from a doppler frequency in this case, you cannot detect whether it was the lower or the higher doppler frequency.



4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
X 3
Y 7500000
Z 4.29833
X -2
Y 4500000
Z 1.27849
X -1
Y 4500000
Z 1.27849
$\times 10^6$
10
5
0
Range
-6
-4
-2
0
2
4
Doppler