Parameters and Setup

```
fs = 10e6; %hz
fc = 1575.42e6; %hz
fI = 2.716e6; %hz
Ts = 1/fs;
Td = 1e-3; %sec
load('hw2_data_real.mat')
xk = GPS_Data_cut;


% LATEX Interpreter for Plots
interr = 'latex';
% interr = 'none';
set(groot,'defaulttextinterpreter',interr);
set(groot, 'defaultAxesTickLabelInterpreter',interr);
set(groot, 'defaultLegendInterpreter',interr);
```

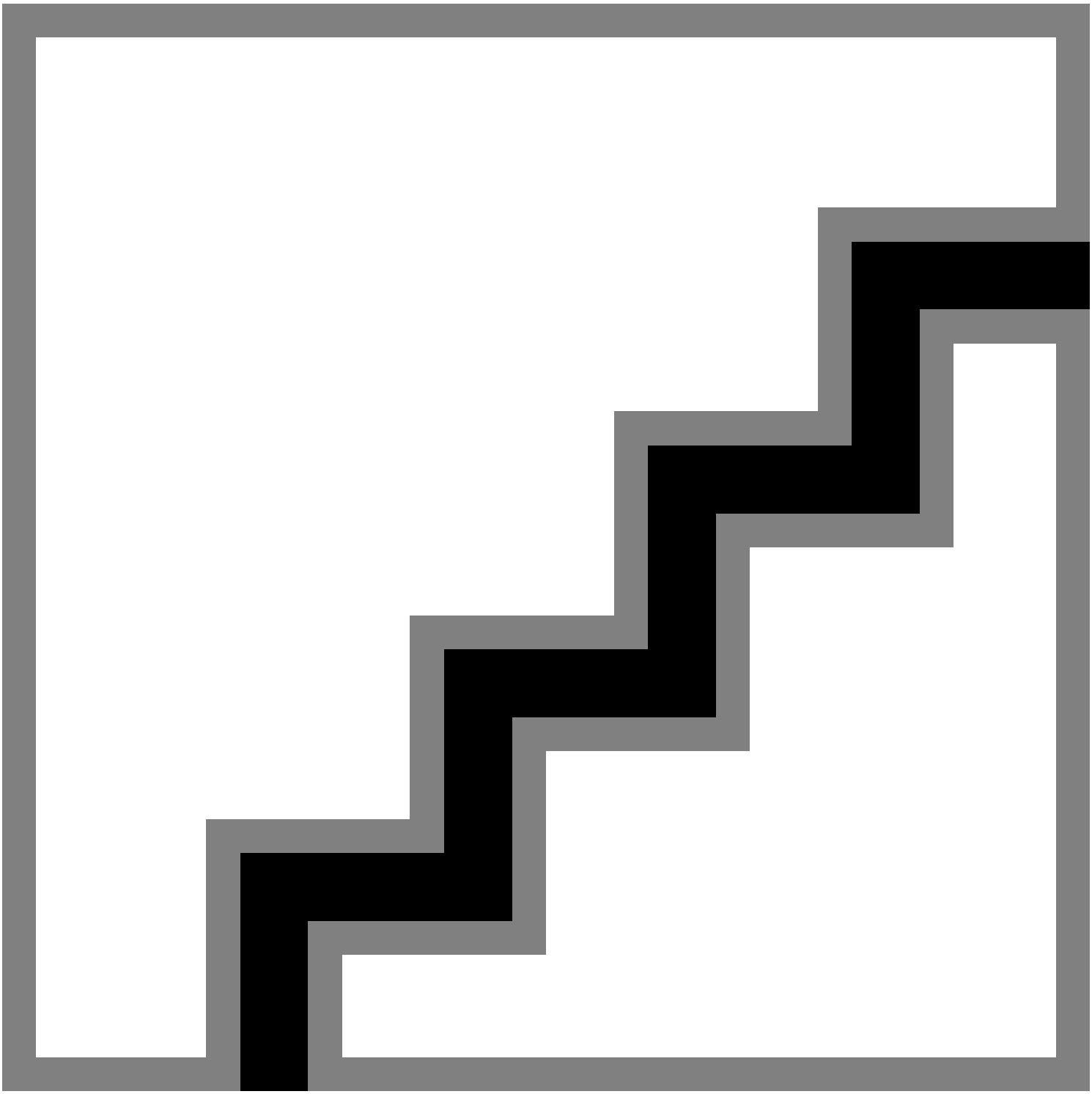
Generate PRN-20

```
prn20taps = [4 7];
[s20, s20b] = genprn(prn20taps);
```

Problem 1

```
ts = linspace(0,1e-3,1e-3*fs)';
s20n = interp1(1:1023,s20b,linspace(1,1023,length(ts)),'previous')';
fD = 500; %hz
IL = cos(2*pi*(fI+fD)*ts).*s20n;
QL = sin(2*pi*(fI+fD)*ts).*s20n;

% s20, IL, and QL for plotting purposes (smooth)
ts_plot = linspace(0,1e-3,100000)';
s20n_plot = interp1(1:1023,s20b,linspace(1,1023,length(ts_plot)),'previous')';
IL_plot = cos(2*pi*(fI+fD)*ts_plot).*s20n_plot;
QL_plot = sin(2*pi*(fI+fD)*ts_plot).*s20n_plot;

subplot(2,1,1)
plot(ts_plot,IL_plot)
xlim([0,50*Ts])
xlabel('Time, $\mu$ seconds')
ylabel('$I_{L}[k]$')
title('Inphase Signal')
hold on
plot(ts,IL,'ro')
legend('Continous Signal','Sampled Signal','Location','NorthEastOutside')
hold off

subplot(2,1,2)
plot(ts_plot,QL_plot)
xlim([0,50*Ts])
xlabel('Time, $\mu$ seconds')
ylabel('$Q_{L}[k]$')
```

```
title('Quadrature Signal')
hold on
plot(ts,QL,'ro')
legend('Continous Signal','Sampled Signal','Location','NorthEastOutside')
hold off
sgtitle('Local Signal PRN 20')
set(gcf,'position',[0,0,1080,800])
```



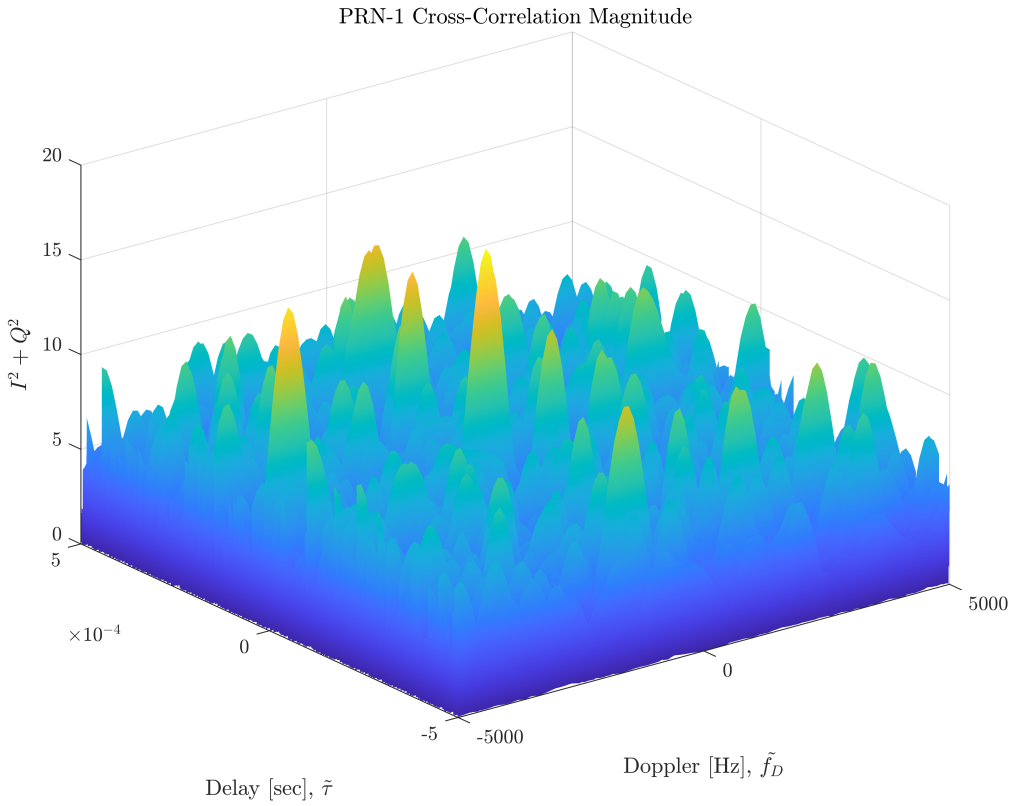
Problem 2

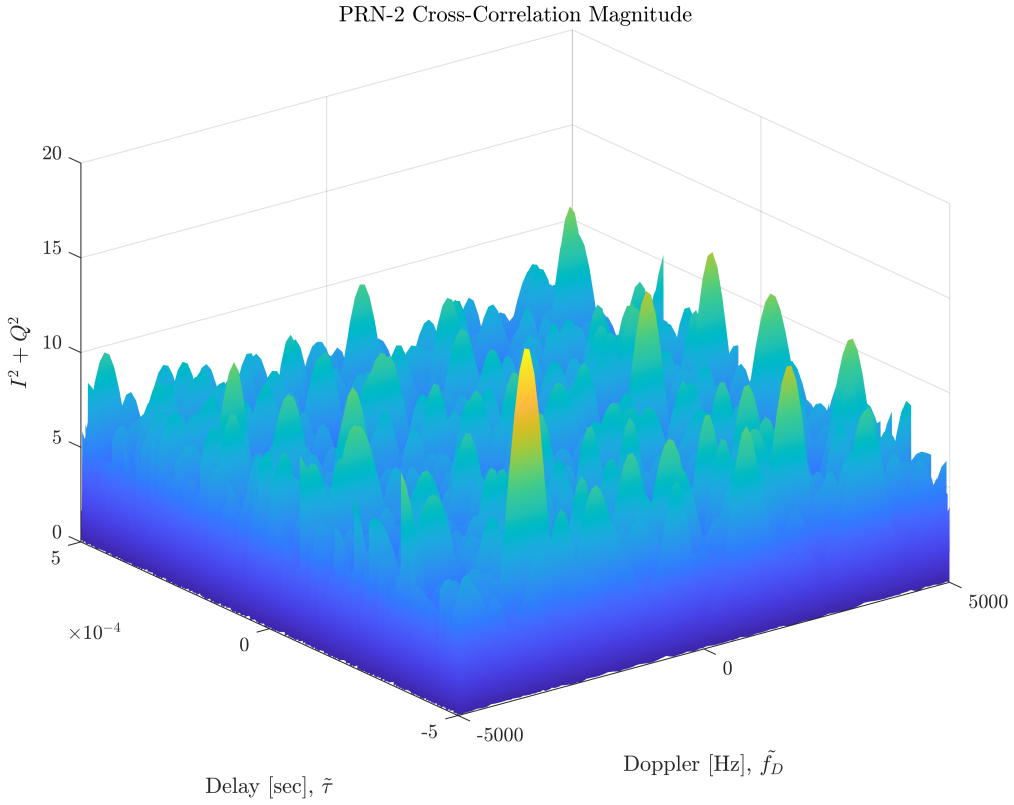
```
c = 299792458; % m/s
wlc = c/fc;
vs = 929; %m/s
vo = 0;
% fs = 1;
fD_max = vs/(wlc);
```

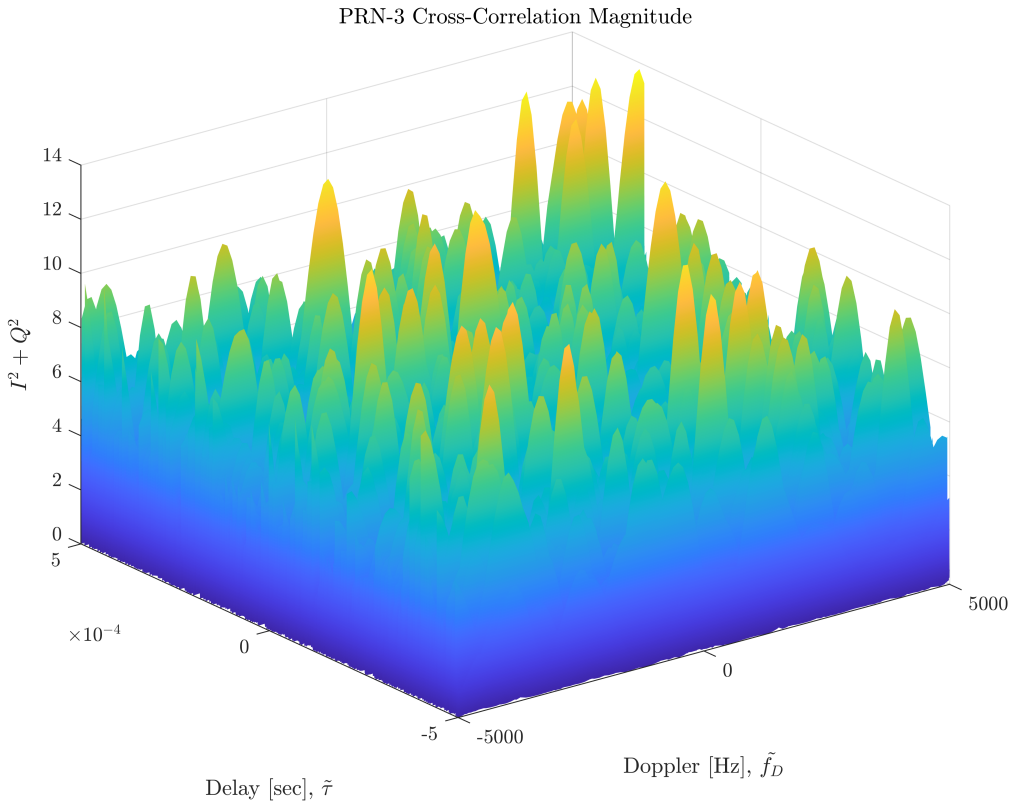
The maximum dopper frequency test range is $-5000\,hz \leq \widetilde{f_D} \leq 5000\,hz$. This is calculated using a radial satellite speed if 929 m/s (source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5467708/). The calculation for the maximum dopper frequency is done by dividing the radial velocity of the satellite with respect to a stationary observer by the wavelength of the carrier frequency. This give us a maximum doppler frequencyof about 4881.9 Hz in either direction.

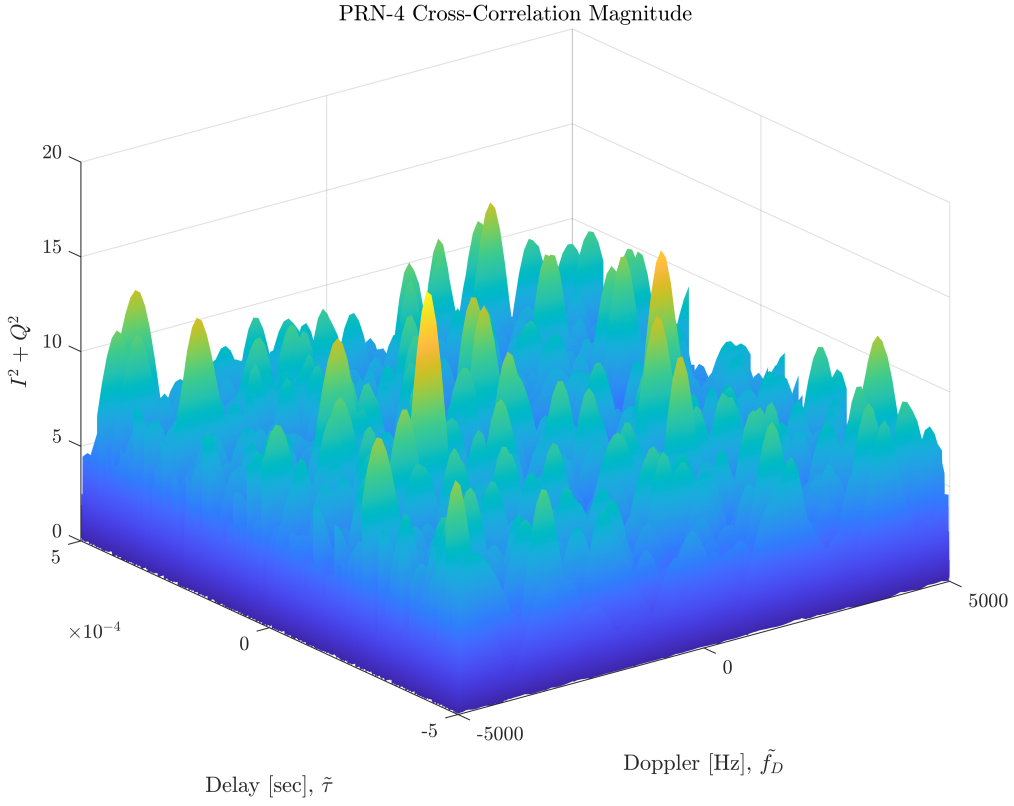
Problem 3:

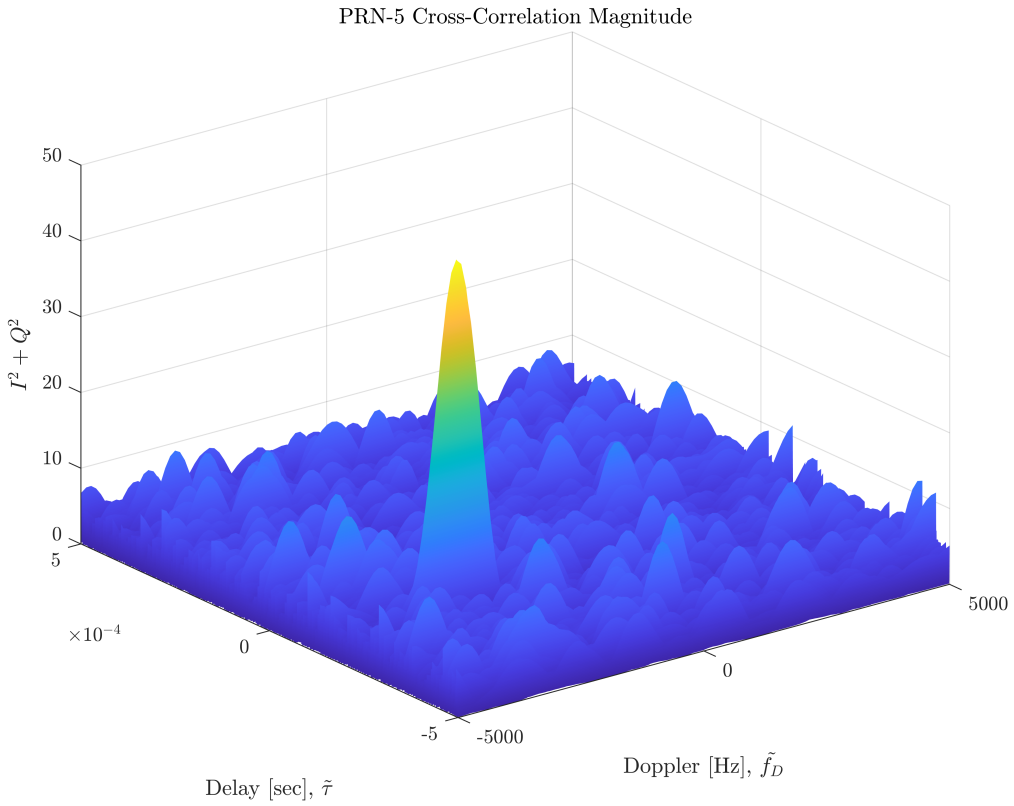
```
fD_test = -5000:100:5000;
t_test = (-5000:4999)*Ts;

% ccIL = zeros(10000,length(fD_test));
% ccQL = zeros(10000,length(fD_test));
% for i = 1:length(fD_test)
%     ILi = cos(2*pi*(fI+fD_test(i))*ts).*xk;
%     QLi = sin(2*pi*(fI+fD_test(i))*ts).*xk;
%     ccIL(:,i) = circcorr(ILi,s20n,1);
%     ccQL(:,i) = circcorr(QLi,s20n,1);
% end
% mag2 = ccIL.^2 + ccQL.^2;
% figure
% surf(fD_test,t_test,mag2)
% ylabel('Delay [sec], $\tilde{\tau}$')
% xlabel('Doppler [Hz], $\tilde{f_{D}}$')
% zlabel('$I^2 + Q^2$')
% shading interp
mag2s = {};
for i = 1:36
    mag2s{i} = ccmag(t_test,fD_test,i,xk,fI,ts);
end
```

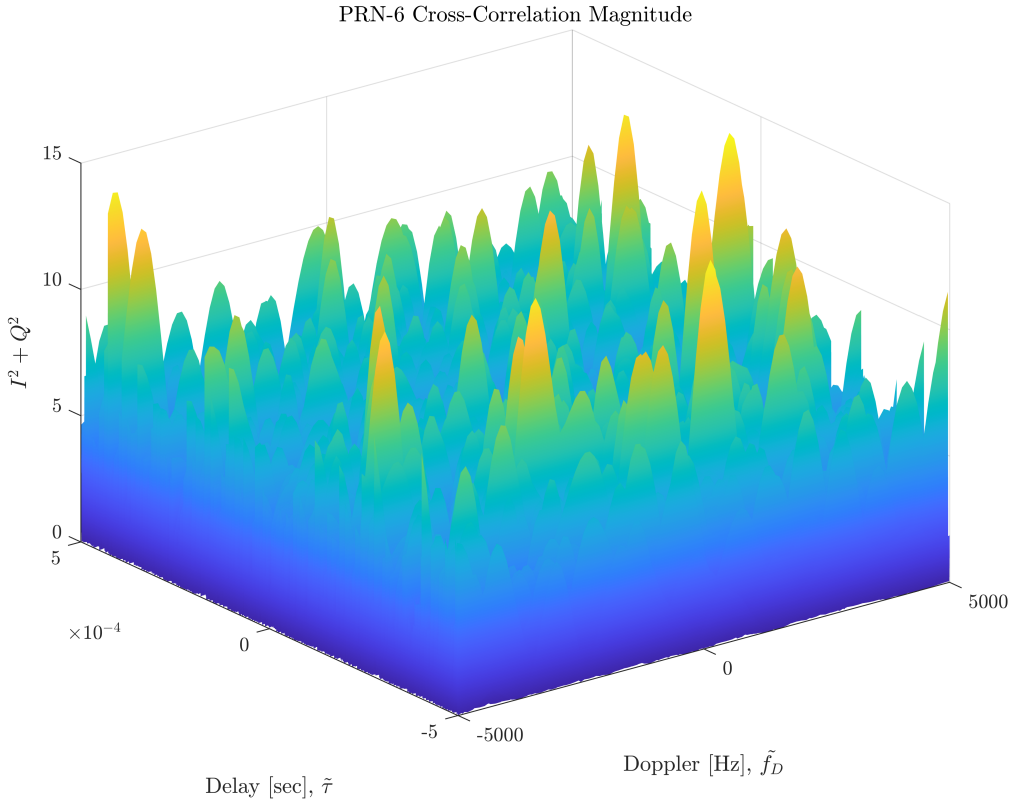

PRN-1 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

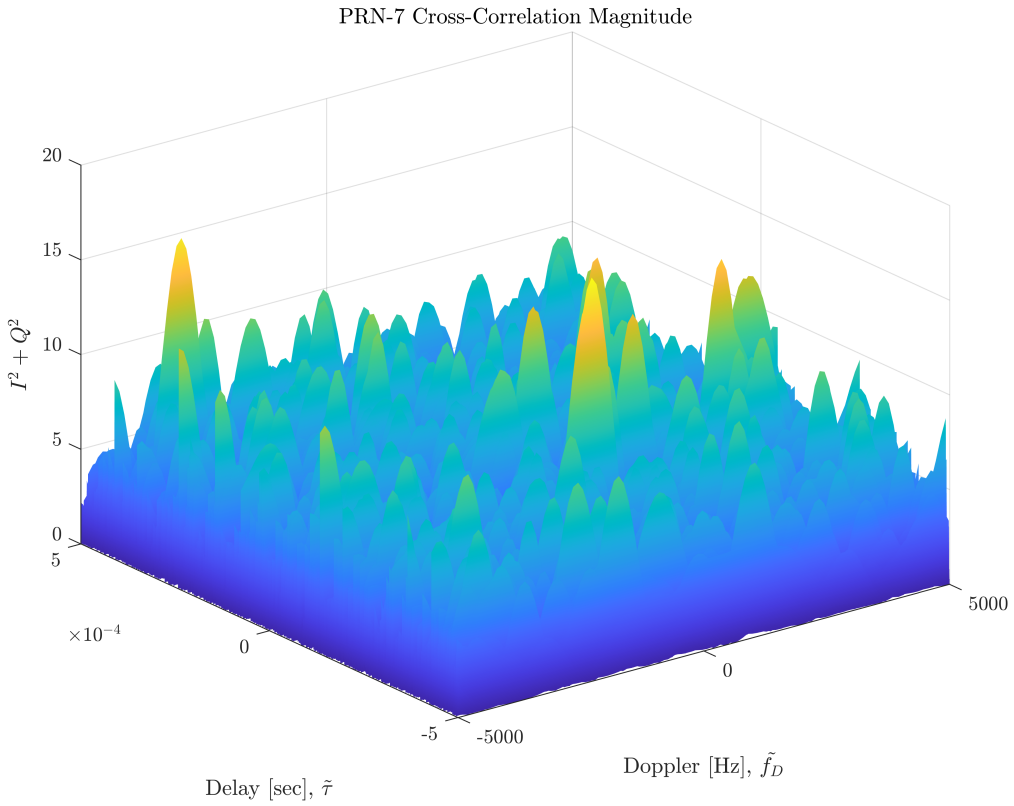

PRN-2 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

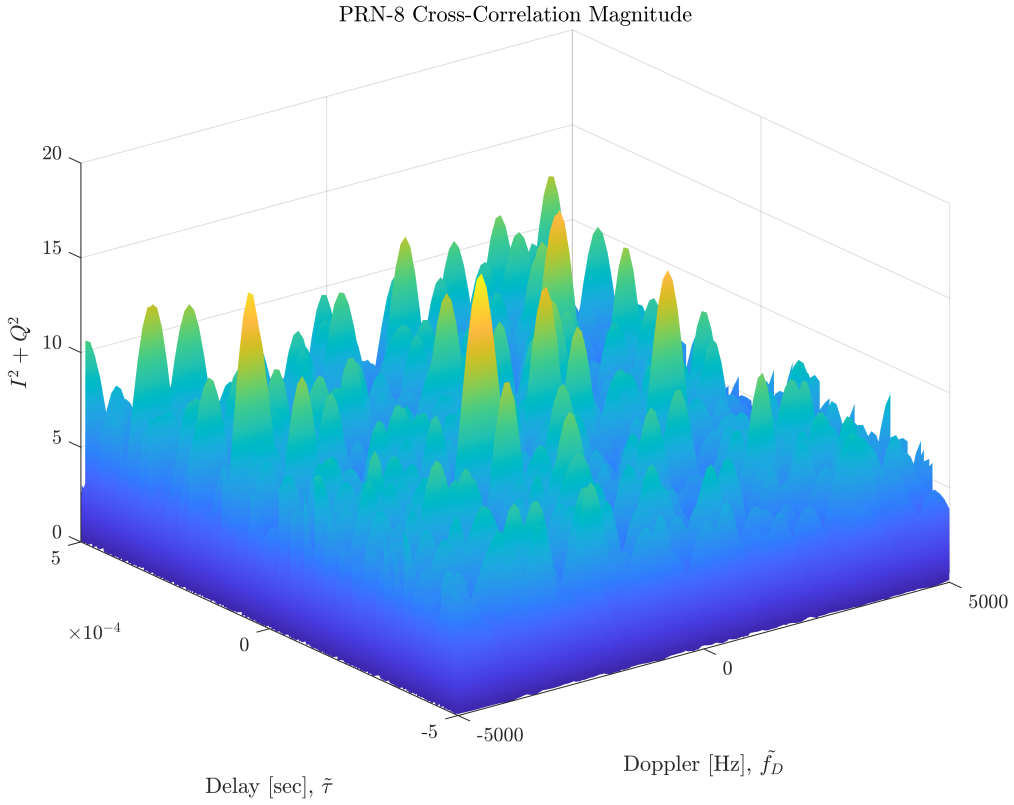

PRN-3 Cross-Correlation Magnitude
$I^2 + Q^2$
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

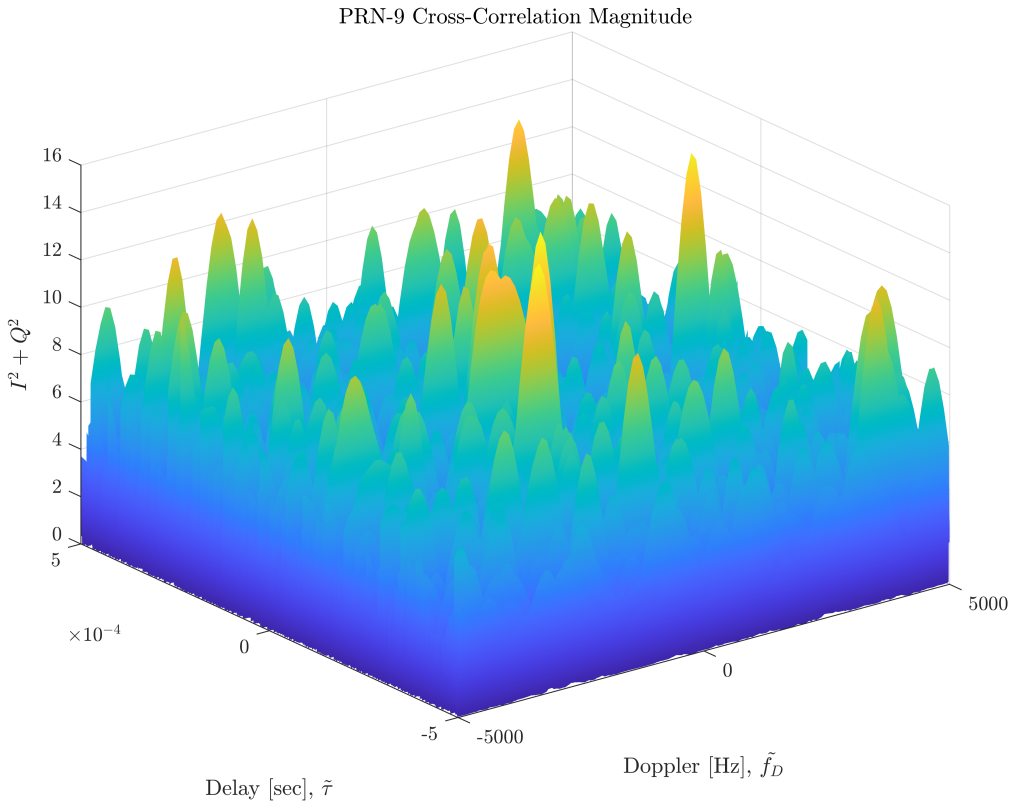

PRN-4 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

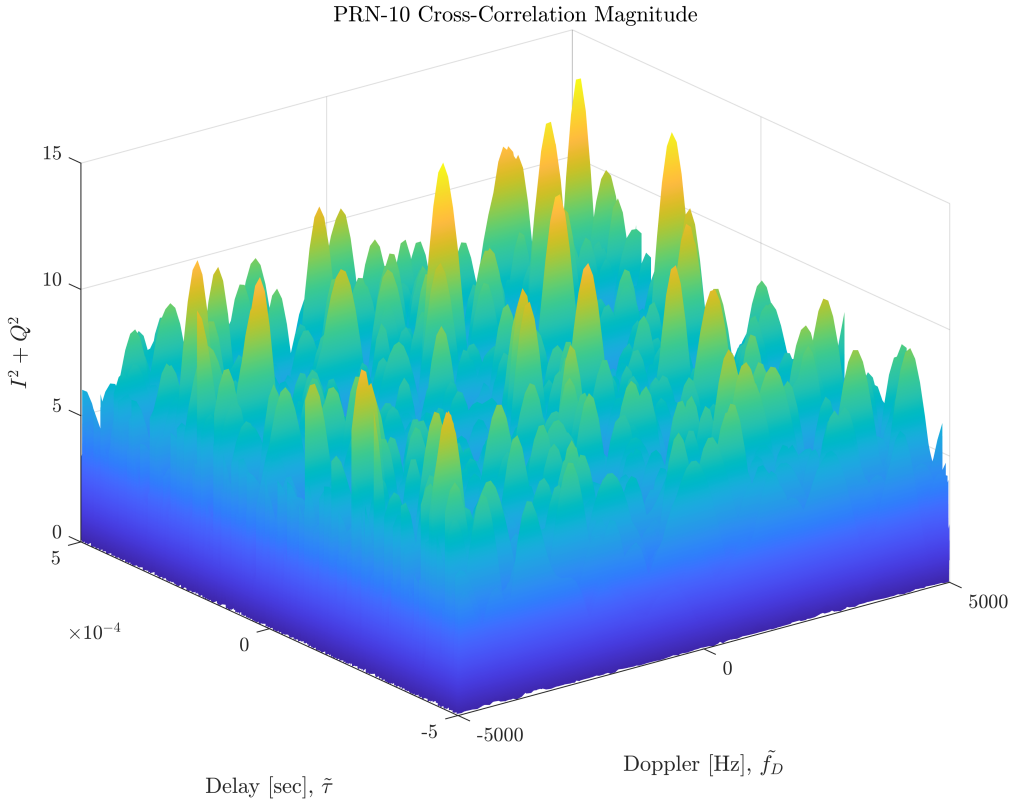

PRN-5 Cross-Correlation Magnitude
$I^2 + Q^2$
50
40
30
20
10
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

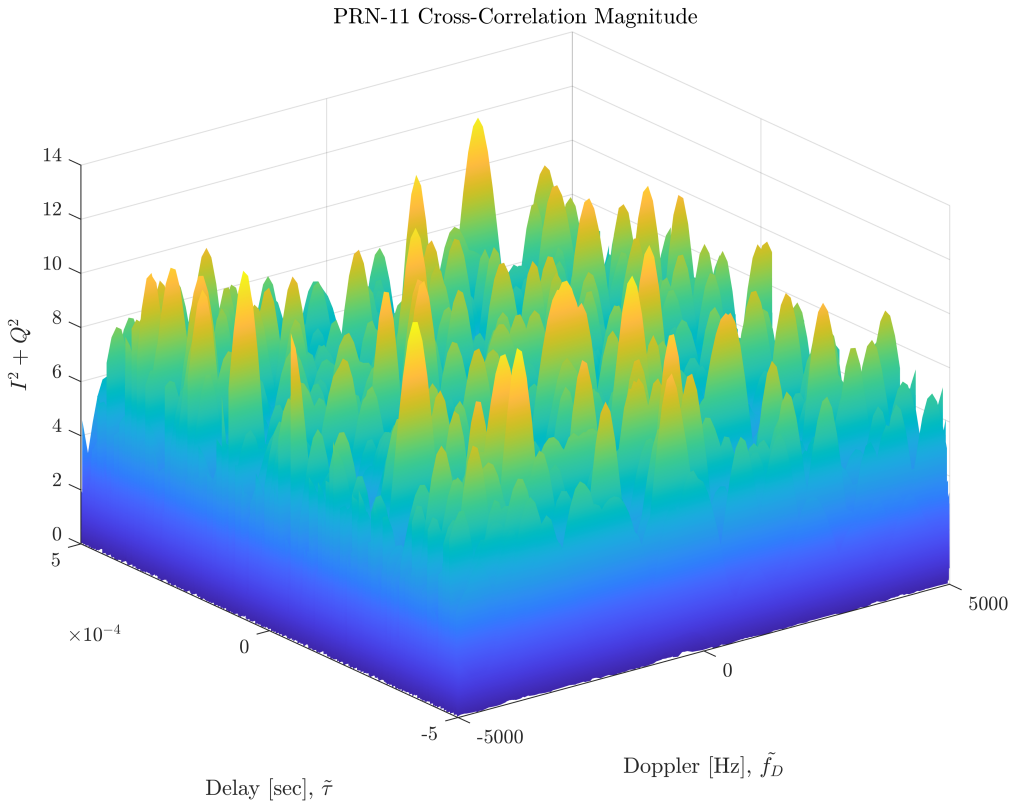

PRN-6 Cross-Correlation Magnitude
$I^2 + Q^2$
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

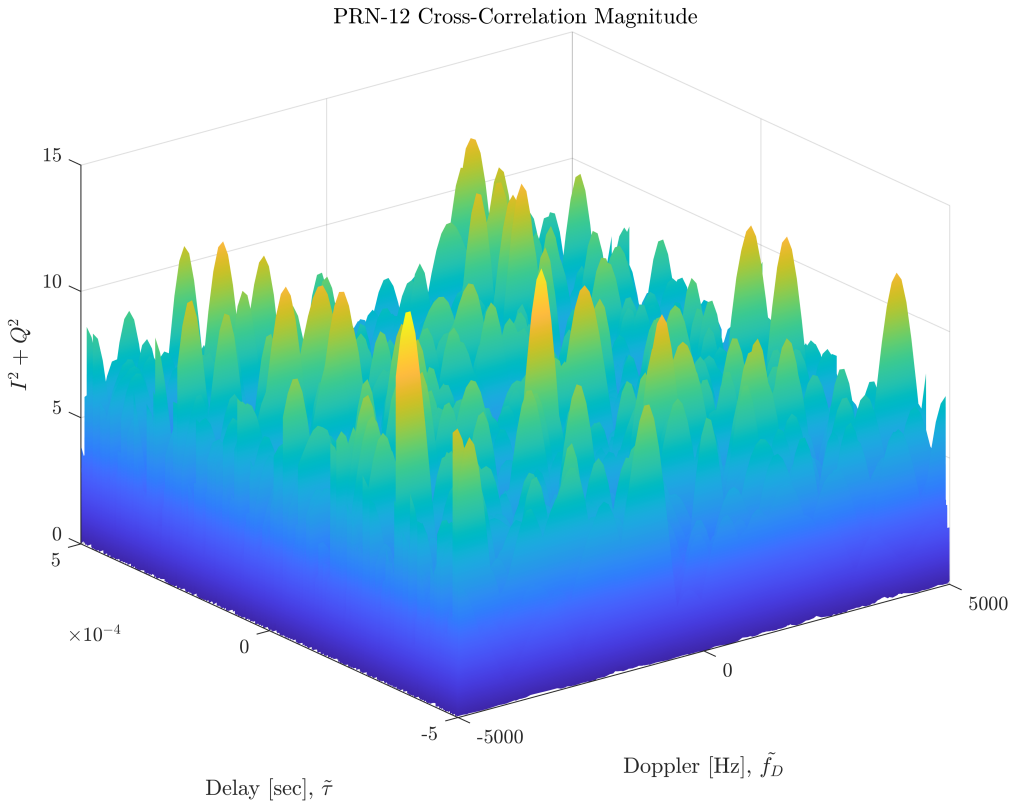

PRN-7 Cross-Correlation Magnitude
20
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

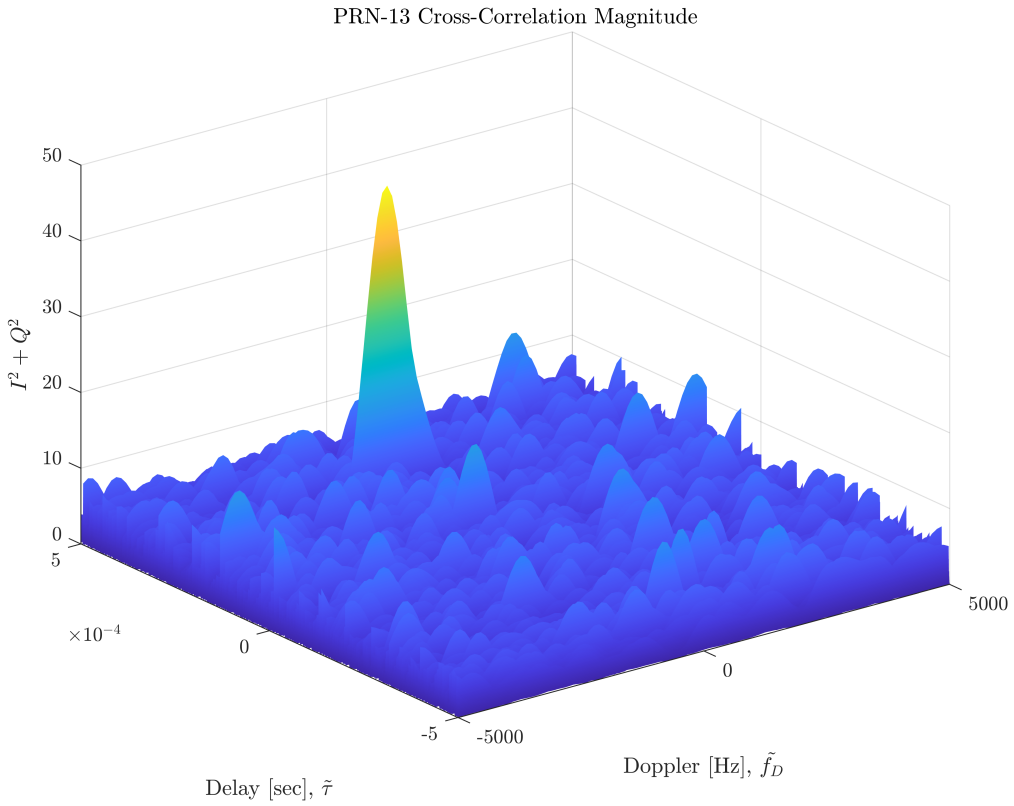

PRN-8 Cross-Correlation Magnitude
20
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

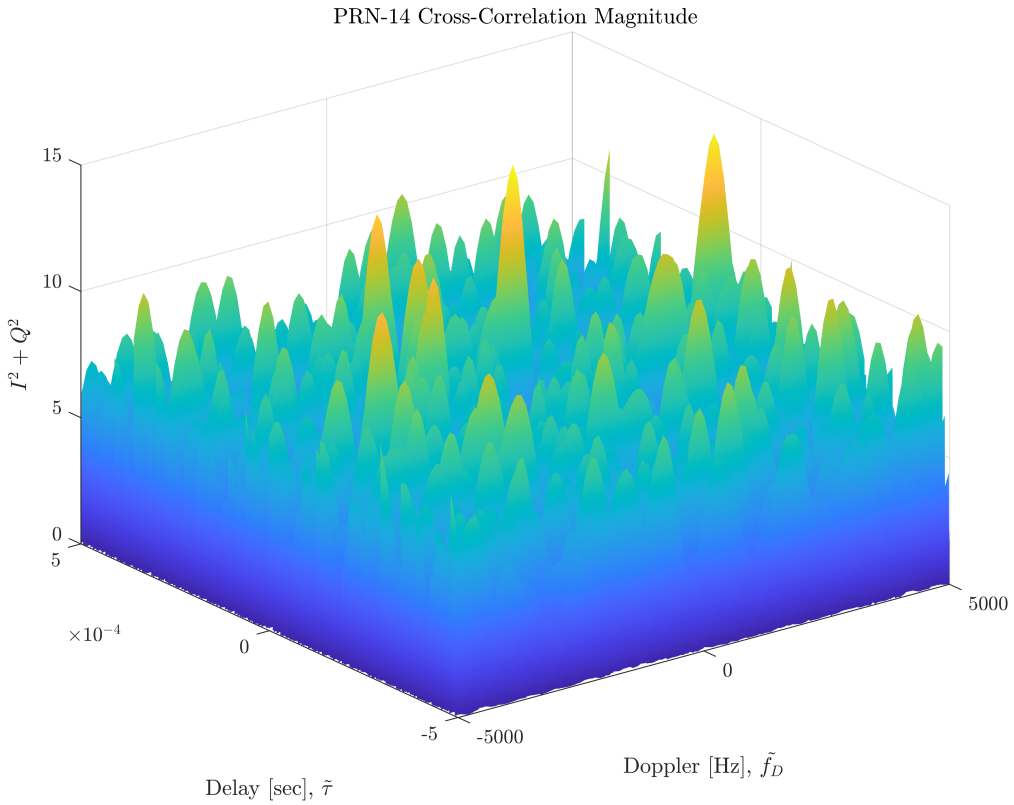

PRN-9 Cross-Correlation Magnitude
$I^2 + Q^2$
16
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

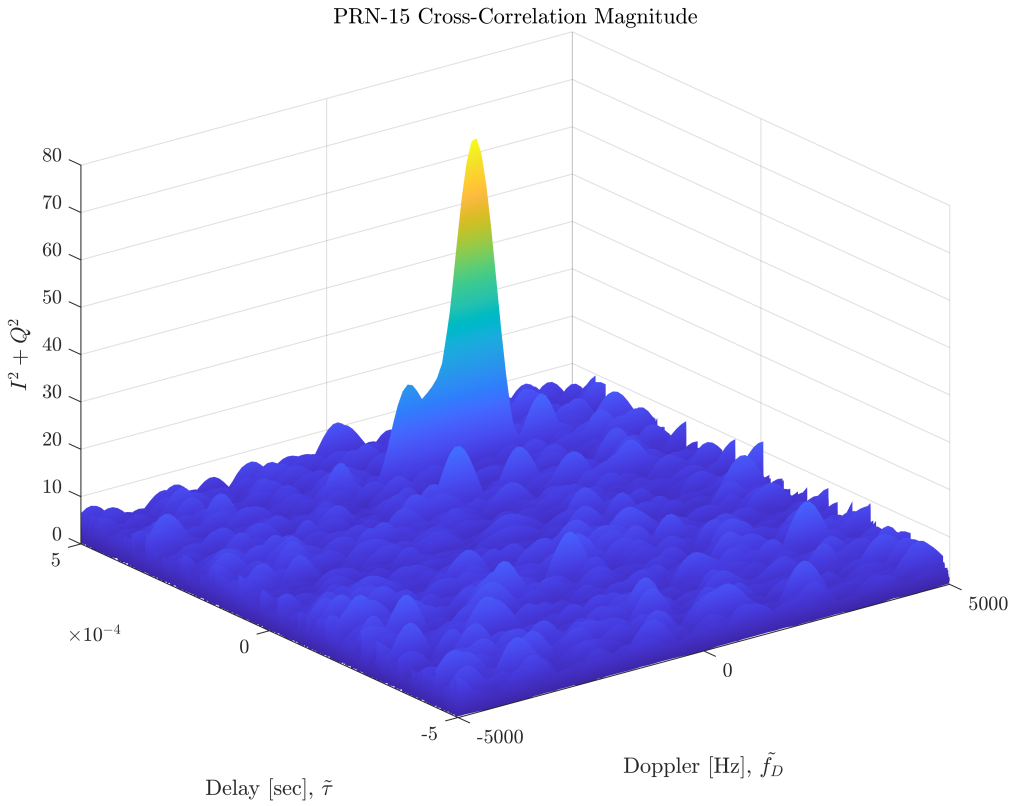

PRN-10 Cross-Correlation Magnitude
$I^2 + Q^2$
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

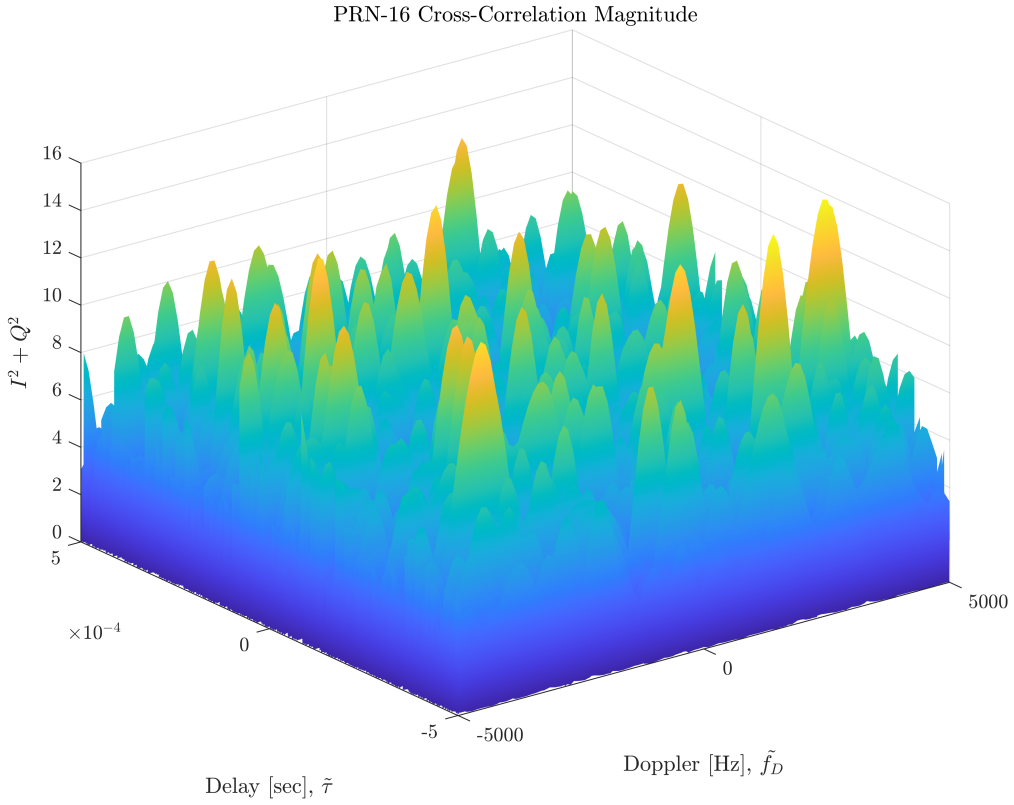

PRN-11 Cross-Correlation Magnitude
$I^2 + Q^2$
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

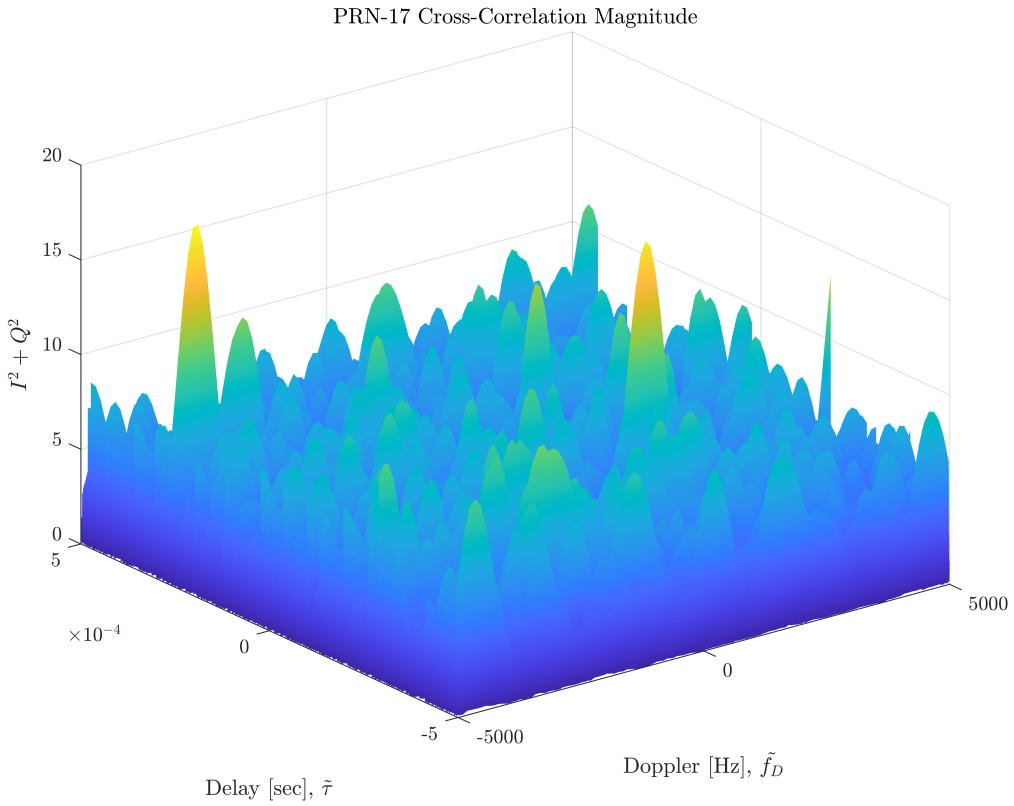

PRN-12 Cross-Correlation Magnitude
$I^2 + Q^2$
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

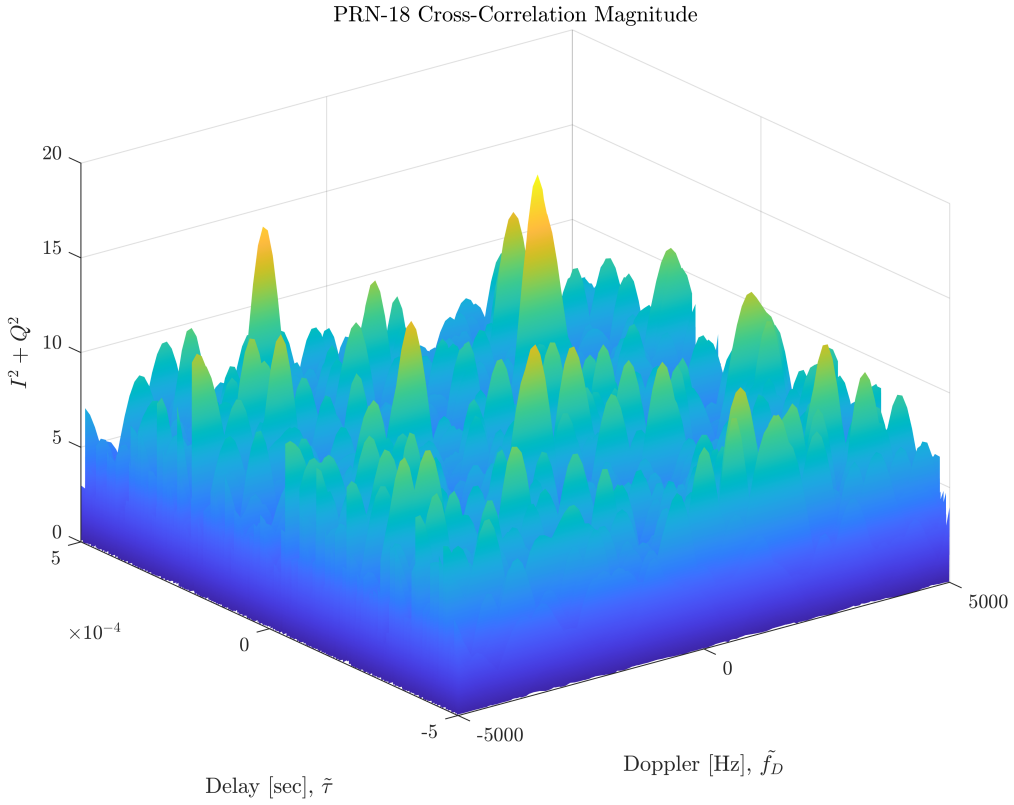

PRN-13 Cross-Correlation Magnitude
$I^2 + Q^2$
50
40
30
20
10
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

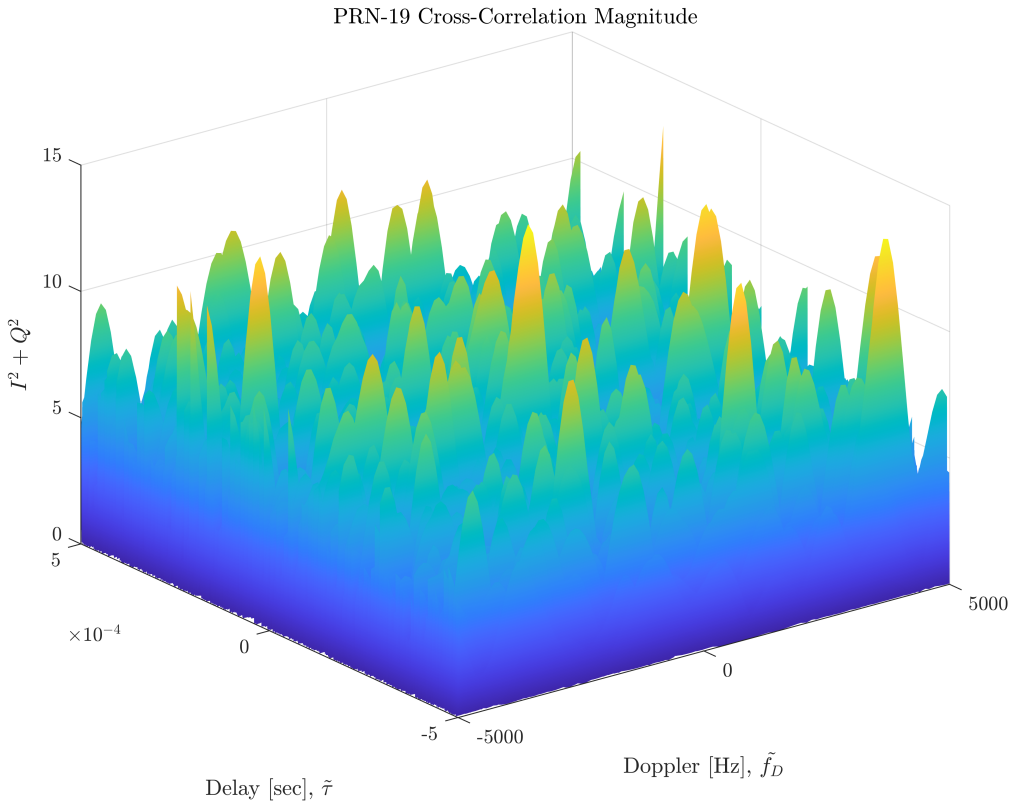

PRN-14 Cross-Correlation Magnitude
$I^2 + Q^2$
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

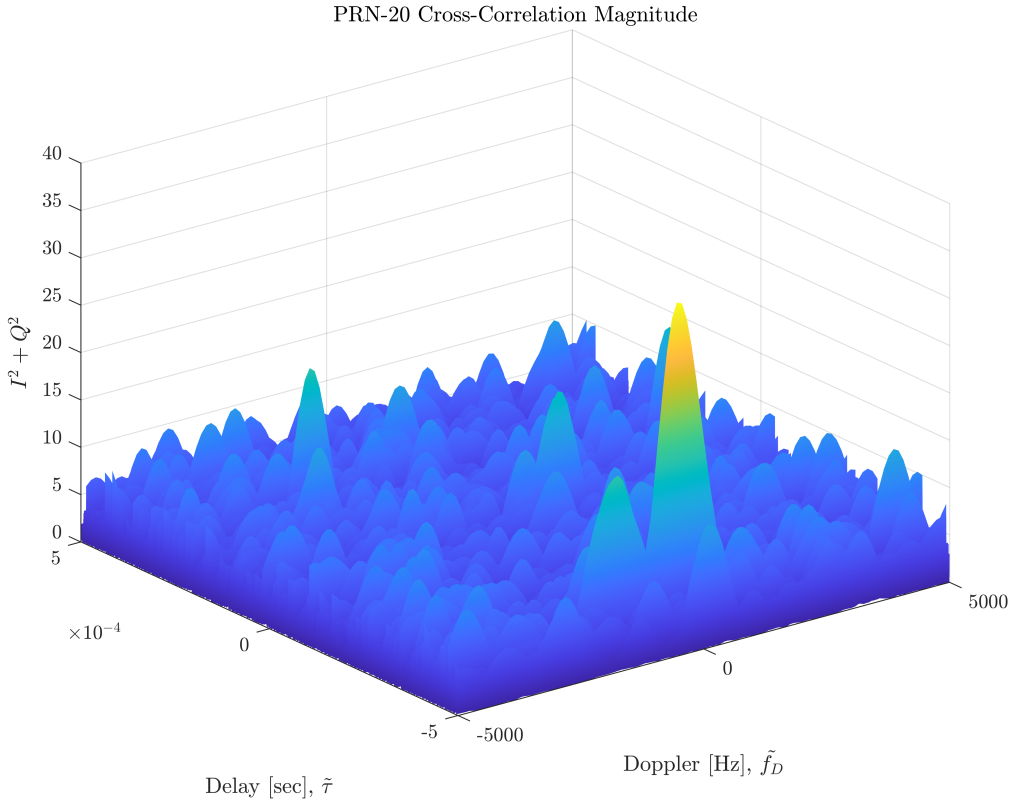

PRN-15 Cross-Correlation Magnitude
80
70
60
50
40
30
20
10
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
Delay [sec], $\tilde{\tau}$
-5000
0
5000
Doppler [Hz], $\tilde{f}_D$

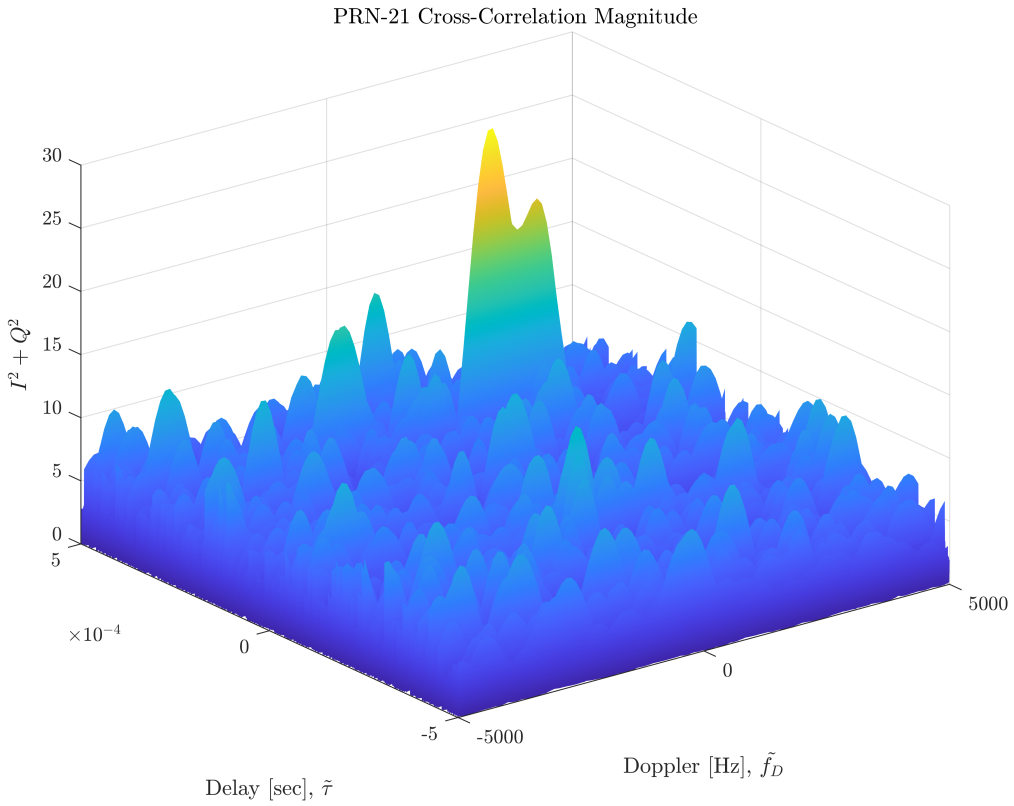

PRN-16 Cross-Correlation Magnitude
16
14
12
10
8
6
4
2
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
Delay [sec], $\tilde{\tau}$
-5000
0
5000
Doppler [Hz], $\tilde{f}_D$

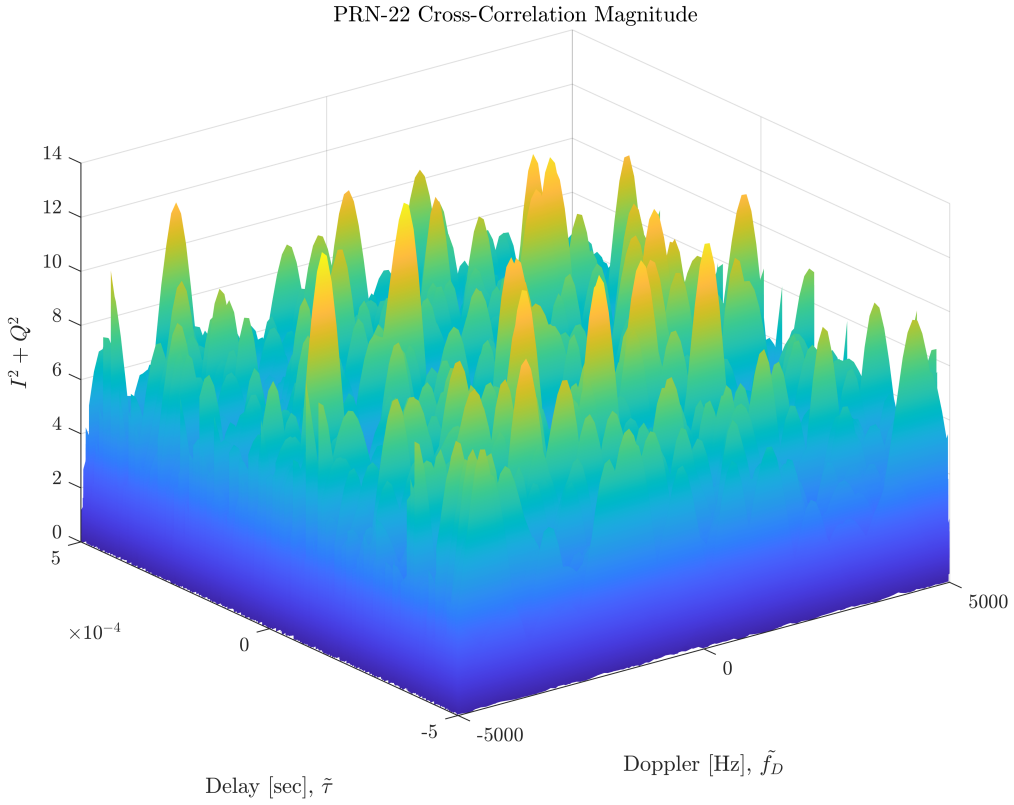

PRN-17 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
Delay [sec], $\tilde{\tau}$
-5000
0
5000
Doppler [Hz], $\tilde{f}_D$

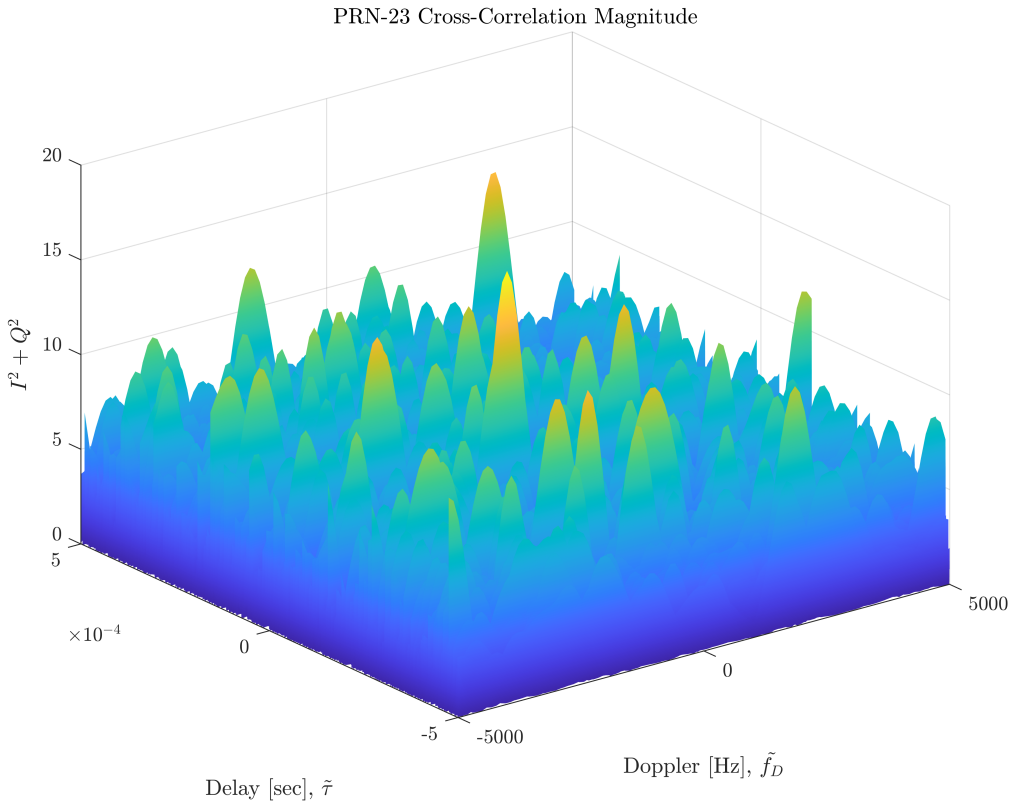

PRN-18 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
Delay [sec], $\tilde{\tau}$
-5000
0
5000
Doppler [Hz], $\tilde{f}_D$

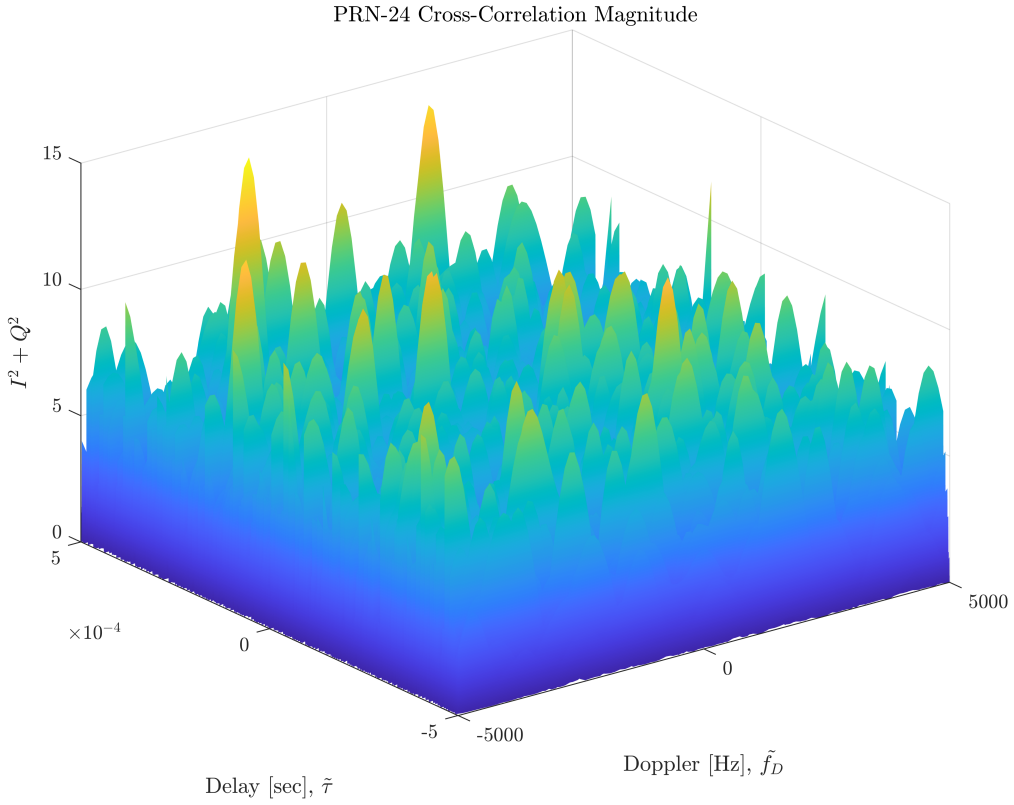

PRN-19 Cross-Correlation Magnitude
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

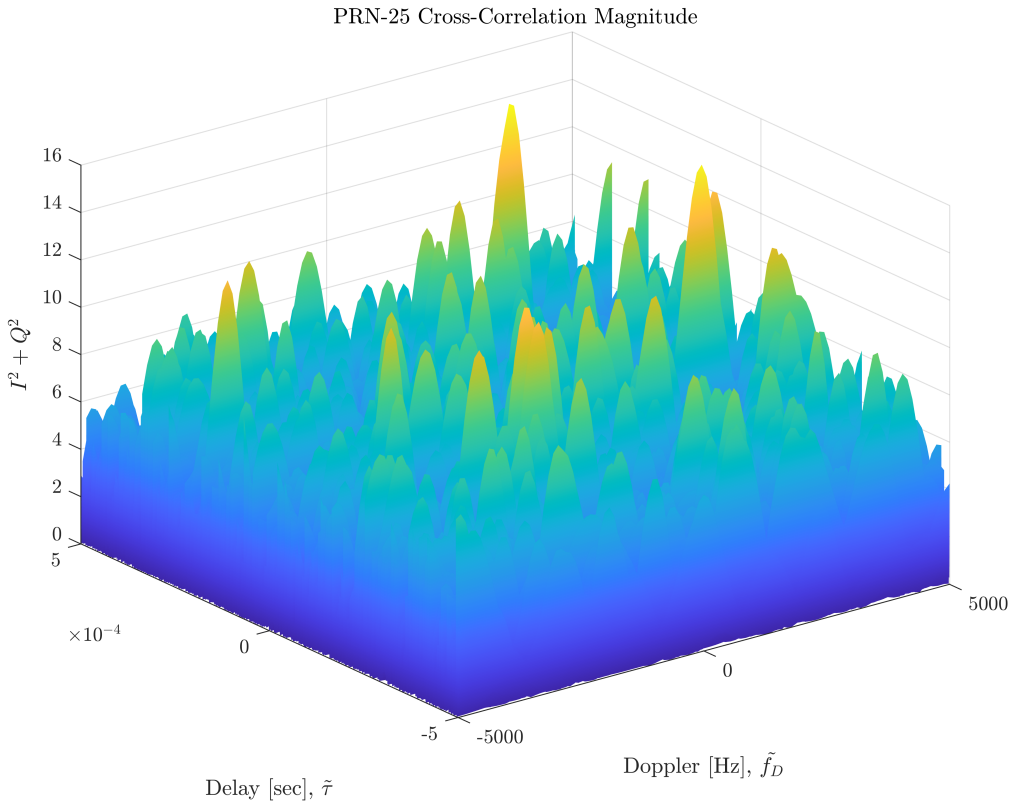

PRN-20 Cross-Correlation Magnitude
40
35
30
25
20
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

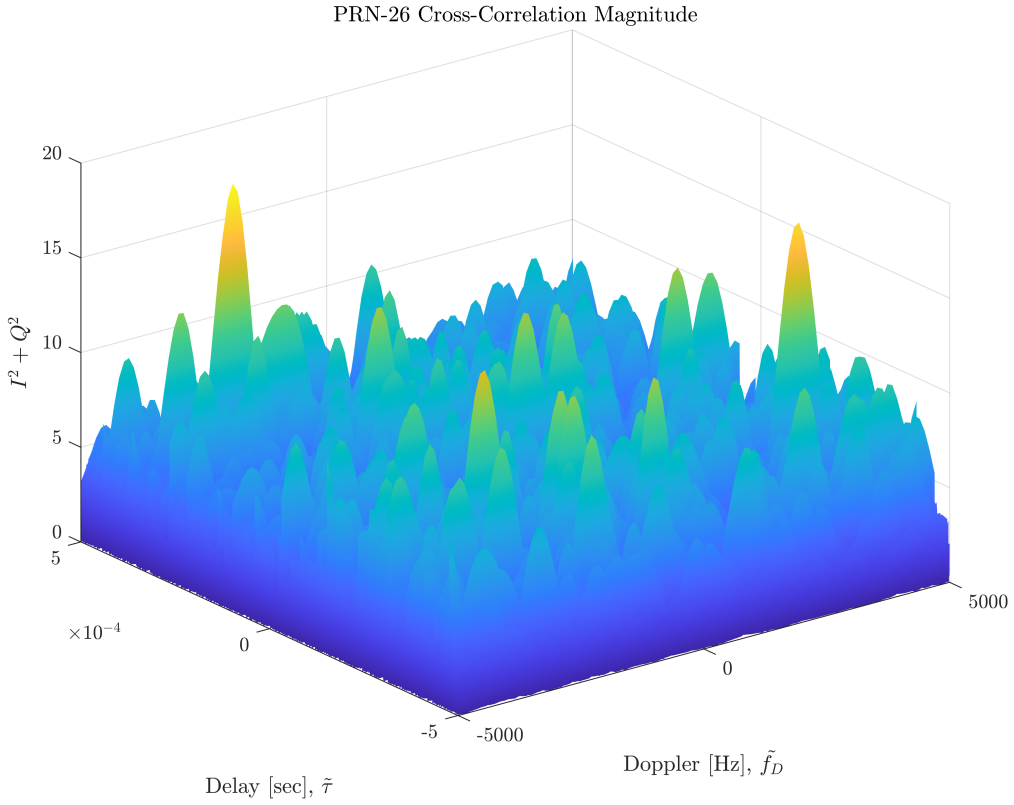

PRN-21 Cross-Correlation Magnitude
30
25
20
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

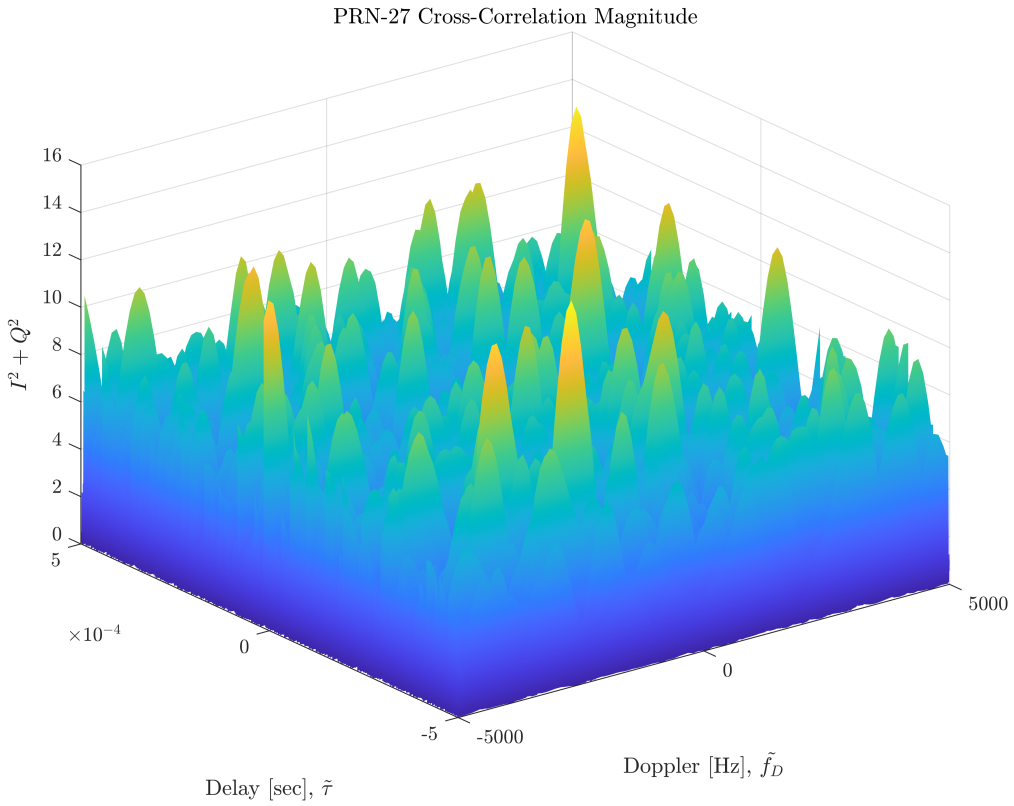

PRN-22 Cross-Correlation Magnitude
14
12
10
8
6
4
2
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

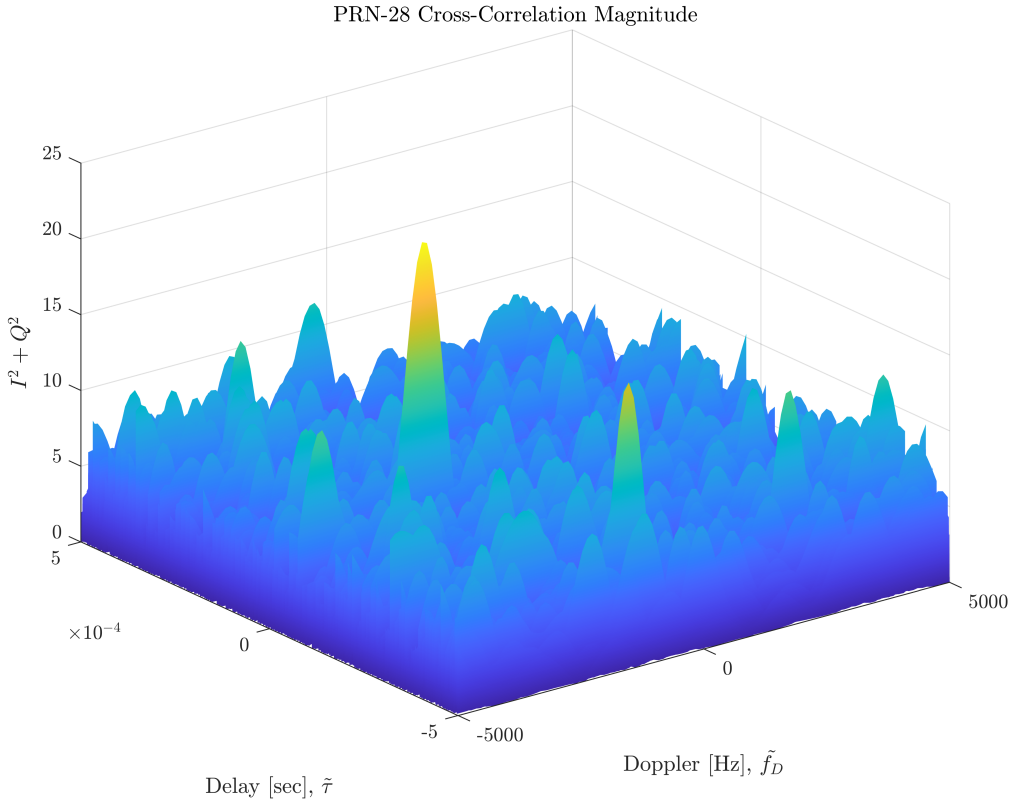

PRN-23 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

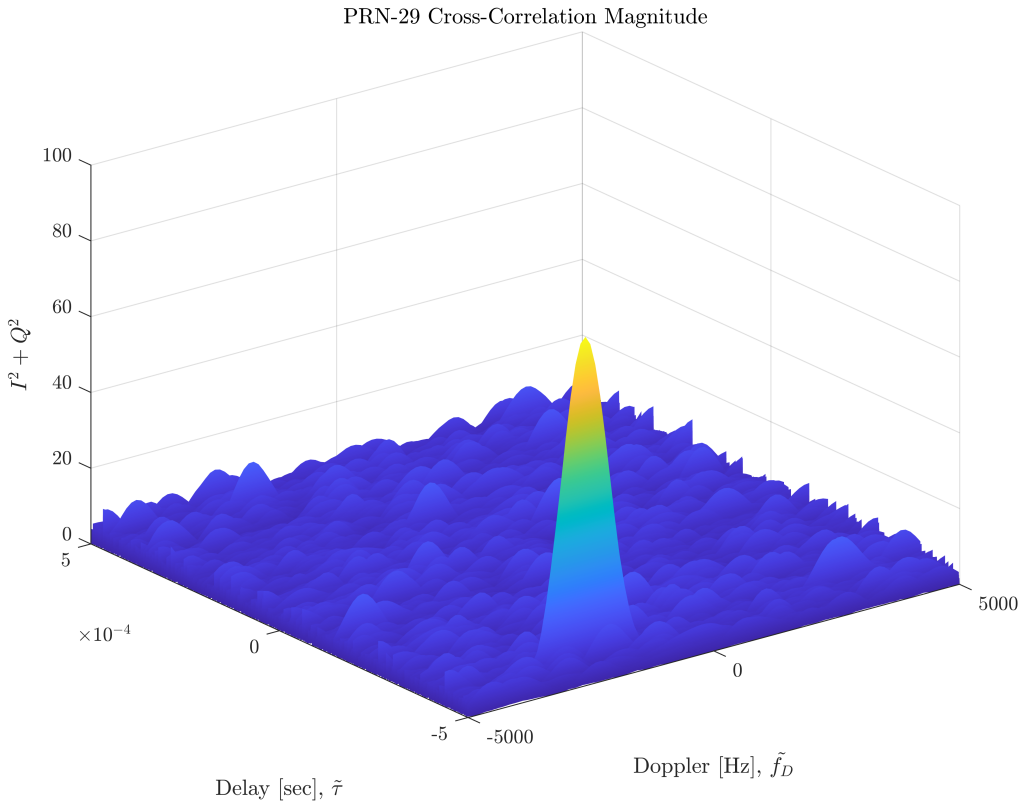

PRN-24 Cross-Correlation Magnitude
$I^2 + Q^2$
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

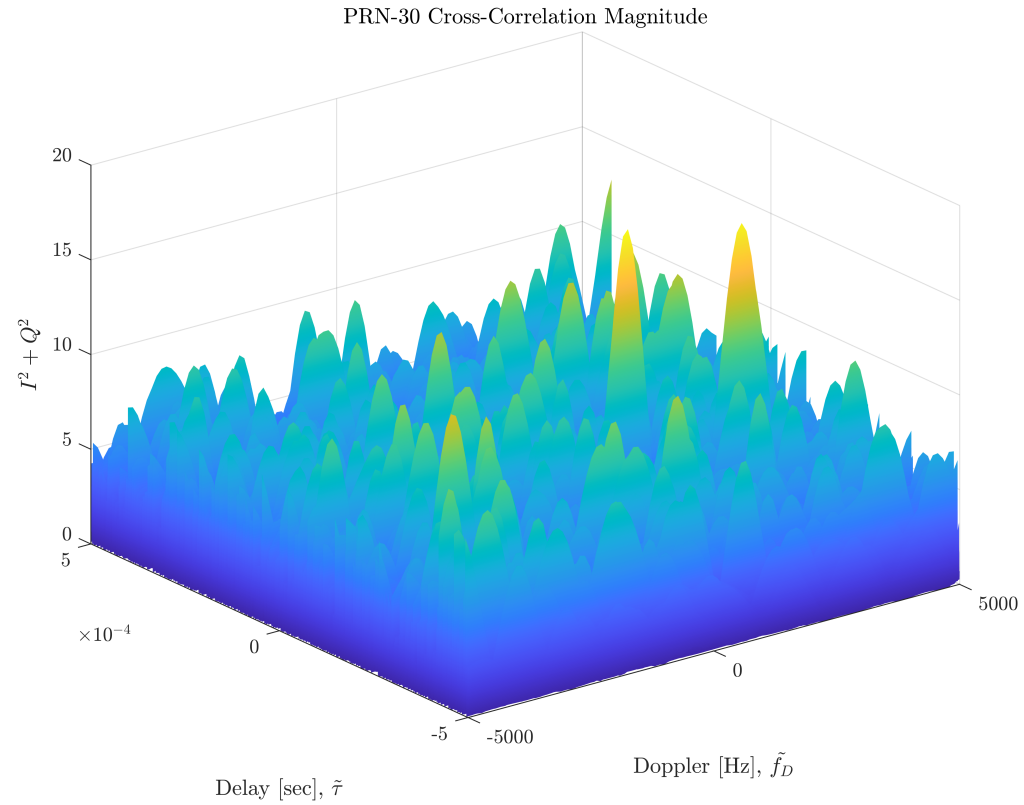

PRN-25 Cross-Correlation Magnitude
$I^2 + Q^2$
16
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

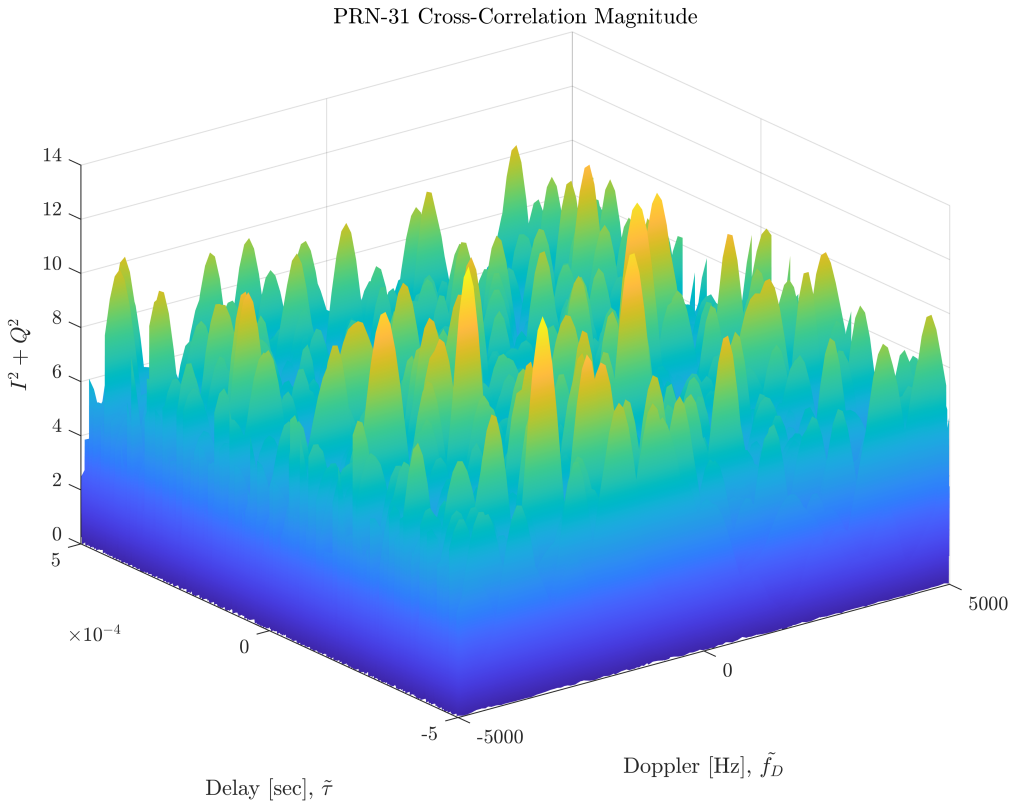

PRN-26 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

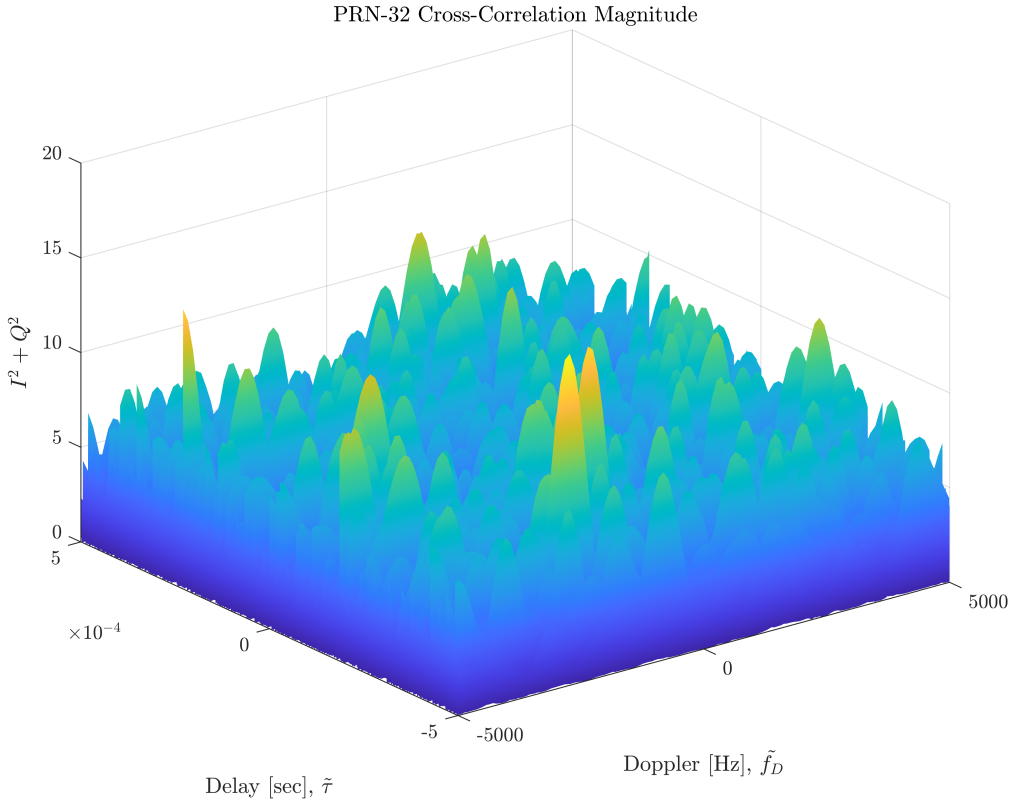

PRN-27 Cross-Correlation Magnitude
$I^2 + Q^2$
16
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

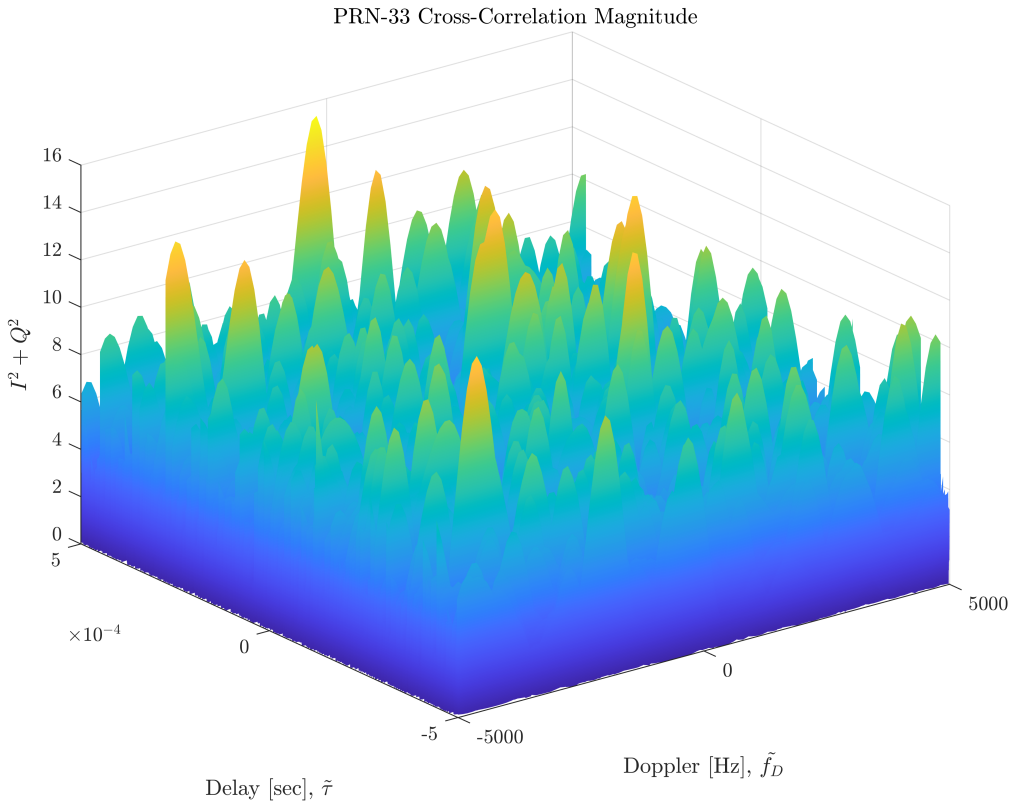

PRN-28 Cross-Correlation Magnitude
$I^2 + Q^2$
25
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

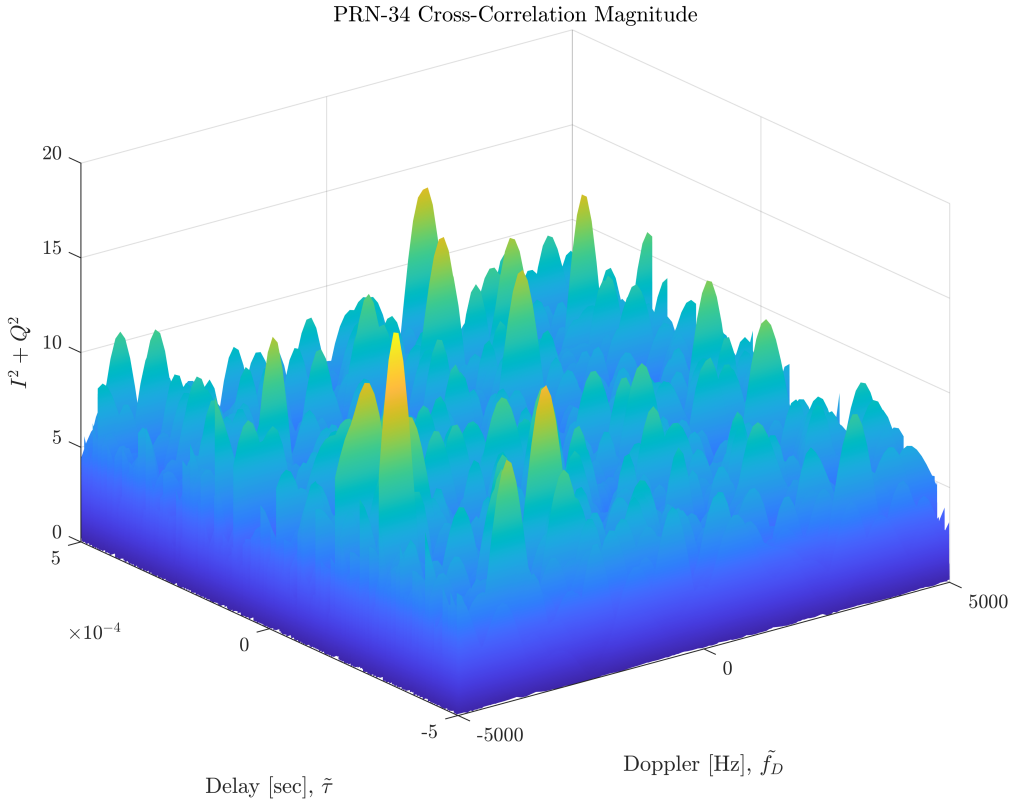

PRN-29 Cross-Correlation Magnitude
100
80
60
40
20
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

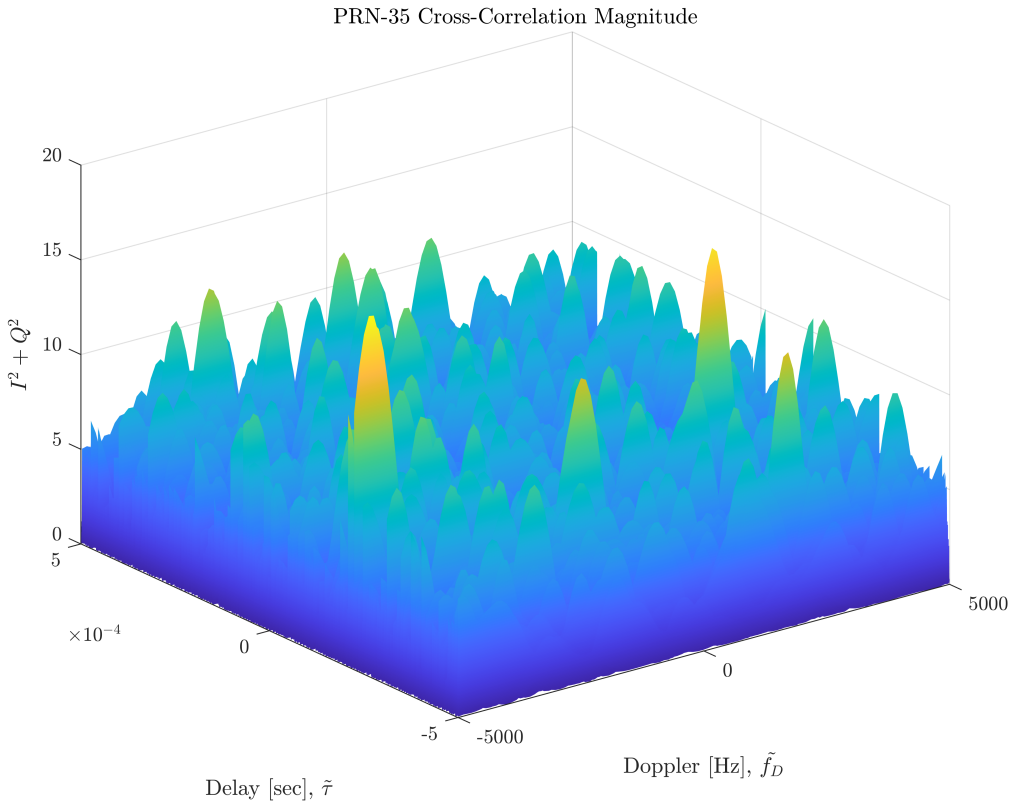

PRN-30 Cross-Correlation Magnitude
20
15
10
5
0
$I^2 + Q^2$
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$

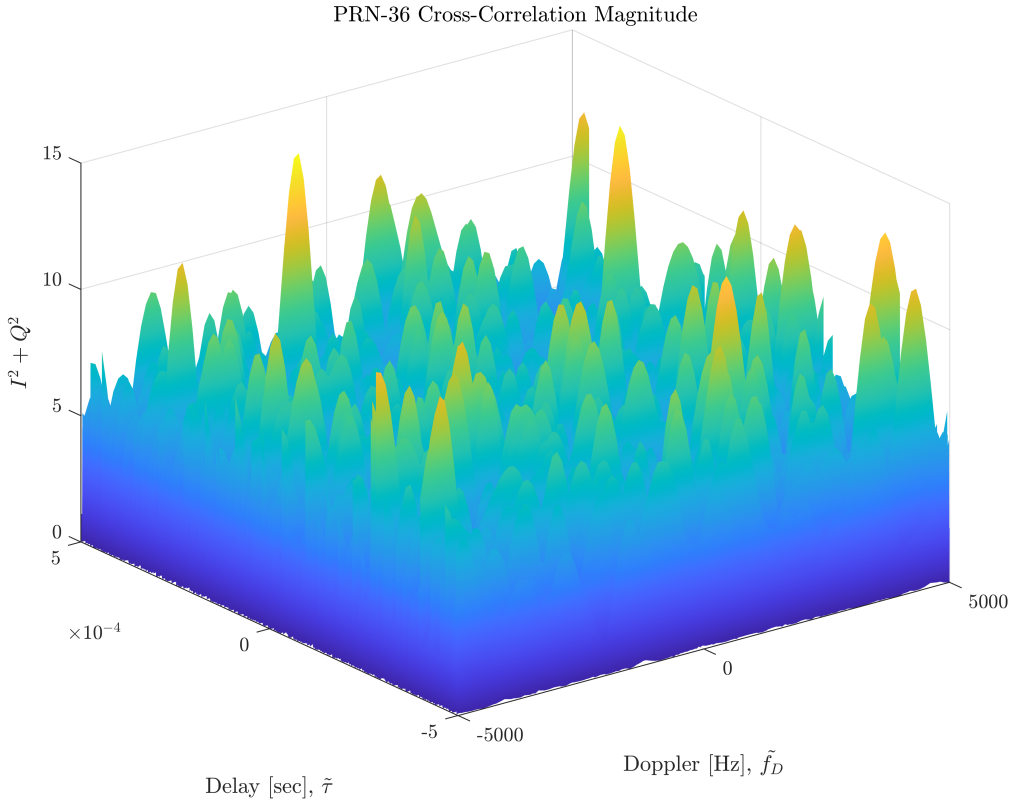

PRN-31 Cross-Correlation Magnitude
$I^2 + Q^2$
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$


PRN-32 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$


PRN-33 Cross-Correlation Magnitude
$I^2 + Q^2$
16
14
12
10
8
6
4
2
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$


PRN-34 Cross-Correlation Magnitude
$I^2 + Q^2$
20
15
10
5
0
5
$\times 10^{-4}$
0
-5
-5000
0
5000
Delay [sec], $\tilde{\tau}$
Doppler [Hz], $\tilde{f}_D$






```
[doppler, delay, mag2peak] = findpeaks(mag2s,fD_test,t_test);
```

Problem 4:

```
c_n0 = snr(mag2peak,cell2mat(mag2s(36))) % using prn36 as noise floor
```

```
c_n0 = 1×36
   11.5880   11.6602   10.5470   11.4774   16.0574   10.8139   11.4671   11.6333 ···
```

```
snrcap = 13; %db
sat_detect = find(c_n0 >  snrcap)
```

```
sat_detect = 1×6
     5    13    15    20    21    29
```

```
sat_nodetect = find(c_n0 <=  snrcap)
```

```
sat_nodetect = 1×30
     1     2     3     4     6     7     8     9    10    11    12    14    16 ···
```

```
c_n0(sat_detect),doppler(sat_detect),delay(sat_detect)
```

```
ans = 1×6
   16.0574   15.5133   17.7219   14.6387   13.7227   18.5708
ans = 1×6
       -2700        -300        1800        -100        1700       -2200
ans = 1×6
10^-3 ×
   -0.1956    0.3003    0.3371   -0.4420    0.2808   -0.4464
```

Functions5

Function 1: Generating Gold Codes

```
function G = gpsgen(ICs, taps)
n = length(ICs);
num = 2^n -1;
G = zeros(num,n);
G(1,:) = ICs;
for i = 1:num-1
    temp = mod(sum(G(i,taps)),2); % mod2 add
    G(i+1,2:n) = G(i,1:n-1); % shift
    G(i+1,1) = temp; % replace first index
end
end
```

Function 2: Binary Phase Shift Keying

```
function G_b = bpsk(G)
G_b = G;
G_b(G_b == 1) = -1;
G_b(G_b == 0) = 1;
end
```

Function 3: Cycle Add Generator

```
function s_i = cycleadd(G1, G2, prntaps)
G2_i = G2(:,1); % create new vector with values of G2
```

```
for i = 1:length(G2)
    G2_i(i) = mod(sum(G2(i,prntaps)),2); % phase select values from G2 code with PRN ta
end
s_i = mod(G1+G2_i,2); % modulo-2 add G1 and G2 codes
end
```

Function 4: Generate PRN Code

```
function [PRN_code, PRN_code_b] = genprn(prntaps)
g1taps = [3 10]; % Taps used to generate G1
g2taps = [2 3 6 8 9 10]; % Taps used to generate G2
ICs = [1 1 1 1 1 1 1 1 1 1]; % Initial conditions used to Generate both G1 and G2

% Generating both G1 and G2 using function 1
G1 = gpsgen(ICs, g1taps);
G2 = gpsgen(ICs, g2taps);
% Using function 2 to map G1 and G2: [1,0
% PRN 14
PRN_code = cycleadd(G1(:,10),G2,prntaps); % Using function 3 to generate PRN14
PRN_code_b = bpsk(PRN_code); % Binary shifting PRN14 using function 2
end
```

Function 5: Cross-Corellation Magnitude and Plot

```
function [mag2,prn_code,interp_prn] = ccmag(test_delay,test_doppler,prn_number,receive
prn_lib = {[2 6], [3 7], [4 8], [5 9], [1 9], [2 10], [1 8], [2 9], [3 10], [2 3],...
    [3 4], [5 6], [6 7], [7 8], [8 9], [9 10], [1 4], [2 5], [3 6], [4 7], [5 8], [6 9
    [1 3], [4 6], [5 7], [6 8], [7 9], [8 10], [1 6], [2 7], [3 8], [4 9], [5 10], [4 
    [1 7], [2 8]};
prn_taps = cell2mat(prn_lib(prn_number));
[~,prn_code] = genprn(prn_taps);
interp_prn = interp1(1:1023,prn_code,linspace(1,1023,length(test_delay)),'previous')';

ccIL = zeros(10000,length(test_doppler));
ccQL = zeros(10000,length(test_doppler));

for i = 1:length(test_doppler)
    ILi = cos(2*pi*(carrier+test_doppler(i))*time).*interp_prn;
    QLi = sin(2*pi*(carrier+test_doppler(i))*time).*interp_prn;
    ccIL(:,i) = circcorr(received_signal,ILi,1);
    ccQL(:,i) = circcorr(received_signal,QLi,1);
end
mag2 = ccIL.^2 + ccQL.^2;

figure
surf(test_doppler,test_delay,mag2)
ylabel('Delay [sec], $\tilde{\tau}$')
xlabel('Doppler [Hz], $\tilde{f_{D}}$')
zlabel('$I^2 + Q^2$')
shading interp
prntitle = sprintf('PRN-%d Cross-Correlation Magnitude',prn_number);
title(prntitle)
end
```

Function 6: Find Peak

```
function [doppler, delay, mag2peak] = findpeaks(mag2s,test_doppler,test_delay)
j = length(mag2s); mag2peak = zeros(1,36);
delay_i = zeros(1,j); doppler_i = zeros(1,j);
doppler = zeros(1,j); delay = zeros(1,j);
for i = 1:j
    mag2_i = mag2s{i};
    mag2peak(i) = max(max(mag2_i));
    [delay_i(i),doppler_i(i)] = find(mag2_i==mag2peak(i));
    doppler(i) = test_doppler(doppler_i(i));
    delay(i) = test_delay(delay_i(i));
end
end
```

Function 7: Signal to Noise Ratio

```
function [c_n0] = snr(test_peaks,noise_signal)
noise = mean(noise_signal,'all');
for i = 1:length(test_peaks)
    c_n0(i) = 10*log10(test_peaks(i) / noise); %db
end
end
```