```
% Joe Gibson
% EGR 280 - Lab 12
% Applications of Correlation Functions

%Clear the command window and previous variables
clear;
clc;

%Seed the random number generator
SEED = sum(100*clock);
rand('seed', SEED);

% PART 1 %
%%%%%%%%%%
%Determine a quasi random pulse for X
%of 1000 pulses of pulse width 10
X = randomPulse(1000, 10);

%Simulate the round trip transmission by adding noise and a delay
alpha = .01;
delta = 1000;
Y = [zeros((2 * delta), 1); alpha*X];

%Add noise with SNR 20db
SNR = -10;
varX = var(X);
sigmaN = sqrt(varX / (10 ^ (SNR/10)));
N = sigmaN * randn(length(Y), 1);
Y = Y + N;

%Compute the cross-correlation
Ryx = xcorr(Y, X);

%Determine the peak in the cross-correlation
L = length(Ryx);
H = ceil(L / 2) + 1;
[peak, peakTime] = max(Ryx(H:L));

%Detemine X axes
AX = 0:length(X) - 1;
AY = 0:length(Y) - 1;
AR = 0:H - 3;

%Plots:
figure(1);
plot(AX, X);
grid on;
xlabel('t');
ylabel('X(t)');
title('X(t) vs t');
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figure(2);
plot(AY, Y);
grid on;
xlabel('t');
ylabel('Y(t)');
title('Y(t) vs t using SNR = 20dB, alpha = 0.01, delta = 1000');

figure(3);
plot(AR, Ryx(H:L));
grid on;
xlabel('t');
ylabel('Ryx');
title('Ryx vs t using SNR = 20dB, alpha = 0.01, delta = 1000');

% PART 2 %
%%%%%%%%%%
%Define number of samples
numSamples = 2000;

%Define the random phase vector
Theta = randn(numSamples + 1, 1);

%Define the delta t
dT = 0.1;

%Define t vector
t = 0:dT:(dT * numSamples);
t = t';

%Define frequency to be 1 Hz
f = 1 / (100 * dT);

%Define omega
w = 2 * 3.14 * f;

%Define transmission as a function of t
Yp = cos((w * t) + Theta);

%Determine SNR, create, scale, and add noise
SNR = 20;
varTheta = var(Theta);
sigmaN = sqrt(varTheta / (10 ^ (SNR/10)));
N = sigmaN * randn(length(Yp), 1);
Yp = Yp + N;

%Compute the autocorrelation
Ryy = xcorr(Yp);

%Determine the peak in the autocorrelation
```
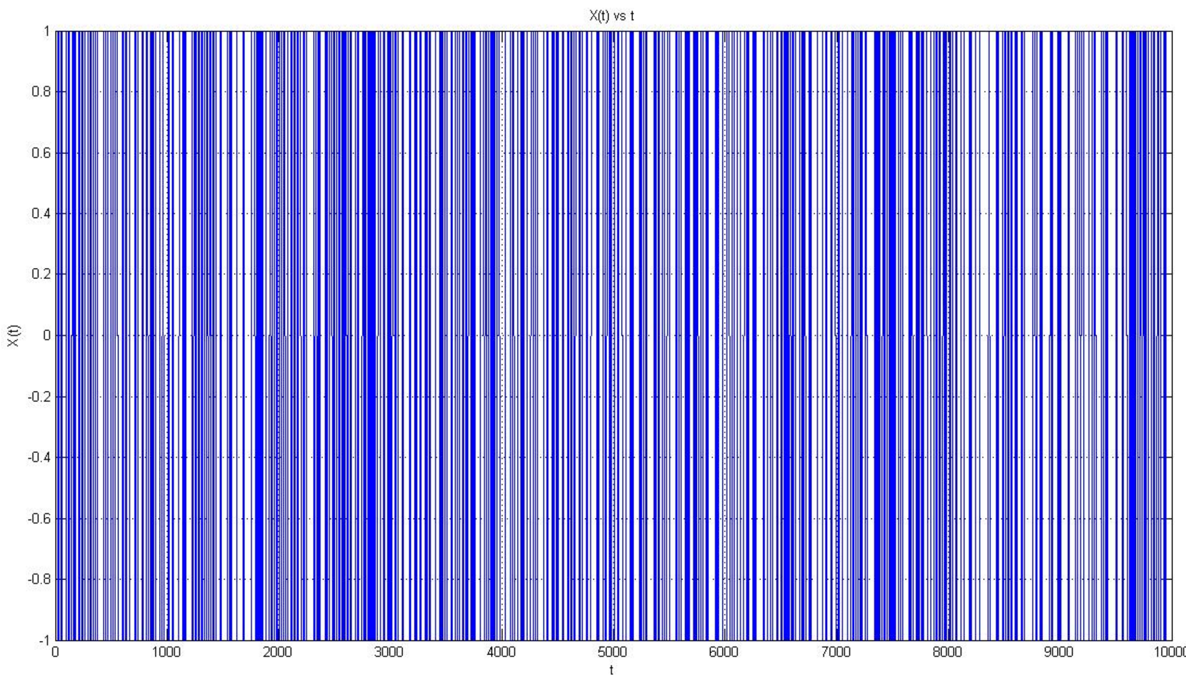

```
L = length(Ryy);
H = ceil(L / 2) + 1;
[pPeak, pPeakTime] = max(Ryy(H:L));

%Plots:
figure(4);
plot(t, Yp);
grid on;
xlabel('t');
ylabel('Yp(t)');
title('Yp(t) vs t');

figure(5);
plot(t, Ryy(H-1:L));
grid on;
xlabel('t');
ylabel('Ryy');
title('Ryy vs t using SNR = 20dB');
```

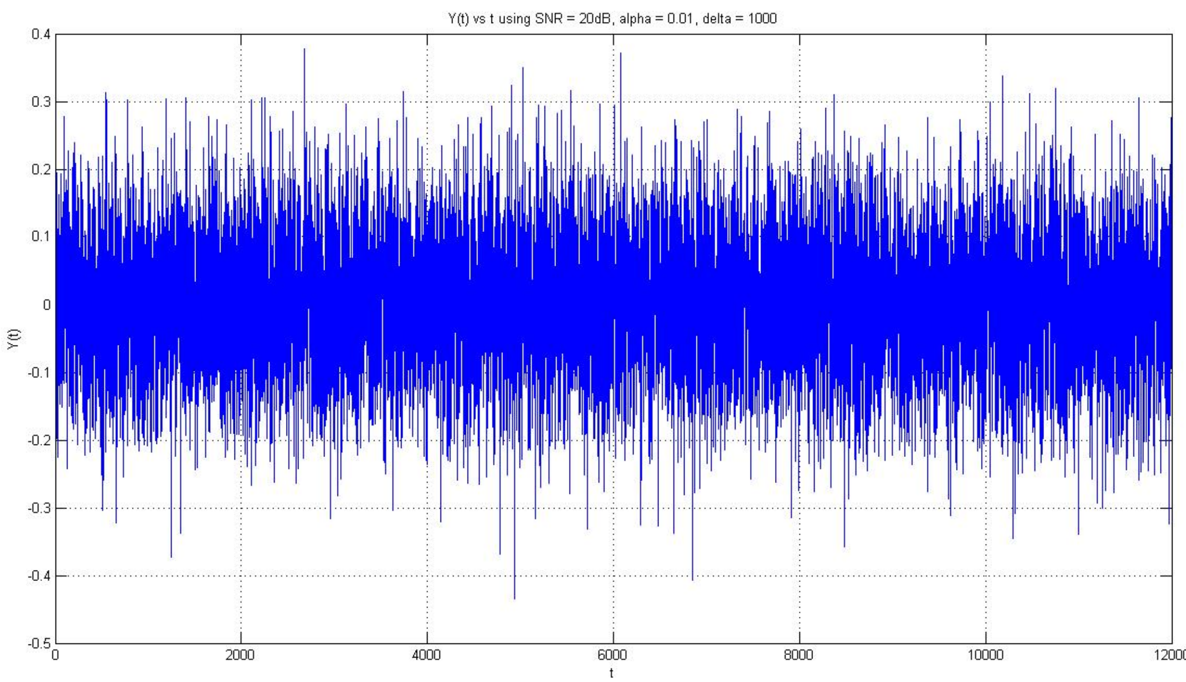
EGR 280 Lab 12
Discussion of Results

1. Part I - Linear
    a. The cross correlation was determined at both 20dB and -10dB. For SNR = 20dB, the peak was found at exactly 2000, which is exactly 2 * delta. For SNR = -10dB, however, the peak was found at 1426, which is not very close (note, for other runs at -10dB the peak was at 21, 615, etc.). The maximum noise ratio that still resulted in a decent estimate for the peak was at 9dB, giving a peak at 1997. This maximum noise ratio increased as the sample size increased. The accuracy did not depend on the amount of delay.
2. Part II Sinusoidal
    a. The autocorrelation was determined using different sample sizes, SNRs, and frequencies. Using a frequency of 1Hz, the Ryy signal was quite clean at 20dB for sample sizes of 200, 2000, and 20000. However, using a -10dB SNR and 2000 sample size resulted in indistinguishable data. The maximum noise was found at -2dB, using 2000 samples with a delta t of 0.1s.
    b. At an SNR of -10dB the frequency was changed from 1Hz until the Ryy signal was distinguishable. This required a frequency of 0.01Hz.
    c. Also, the longer data records (although more difficult to see because it was packed into my small screen) was easily more accurate than the smaller data record runs.
    d. In spite of the aforementioned findings, I was never really able to determine my frequency of 1Hz from the Ryy plots. This may have just been my t axis scaling being off, but I could never figure out why.

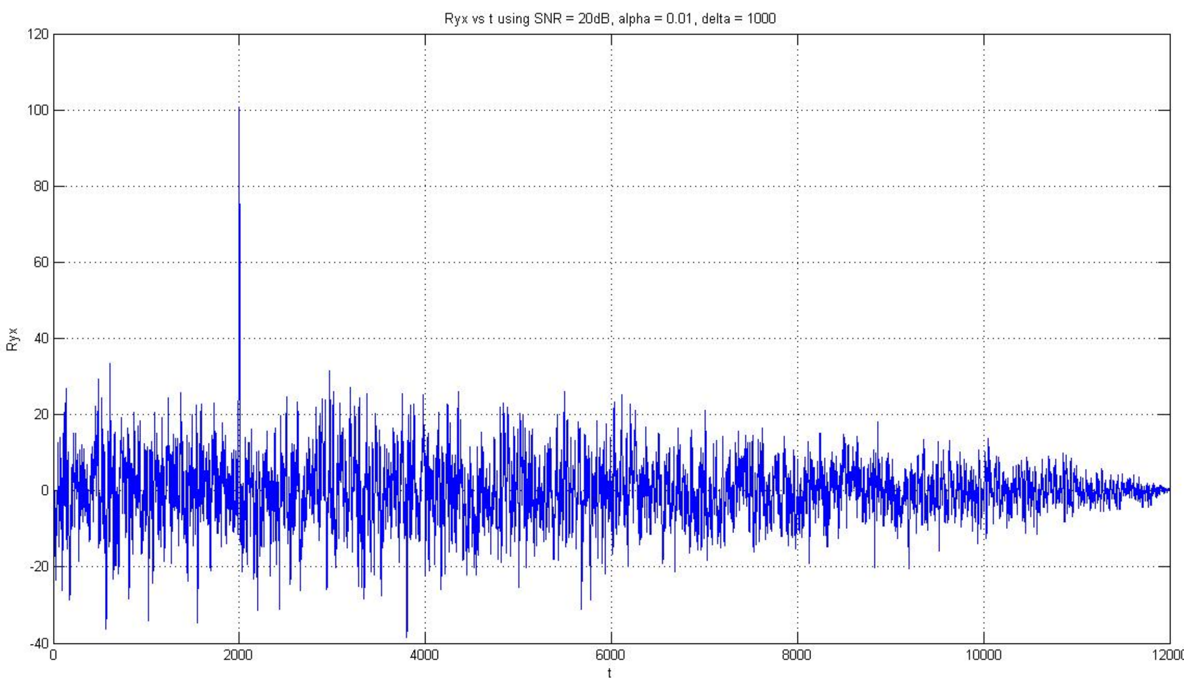
```
function [X] = randomPulse(L, P)
%Usage: [X] = randomPulse(L, P)
%where X is a random pulse vector made up of
%L pulses of pulse length P

%Create X vector
X = zeros((L * P), 1);

%Populate X vector
for i = 1:P:(L * P)
    if(rand() <= 0.5)
        for j = i:(i + P)
            X(j) = -1;
        end
    else
        for k = i:(i + P)
            X(k) = 1;
        end
    end
end
```



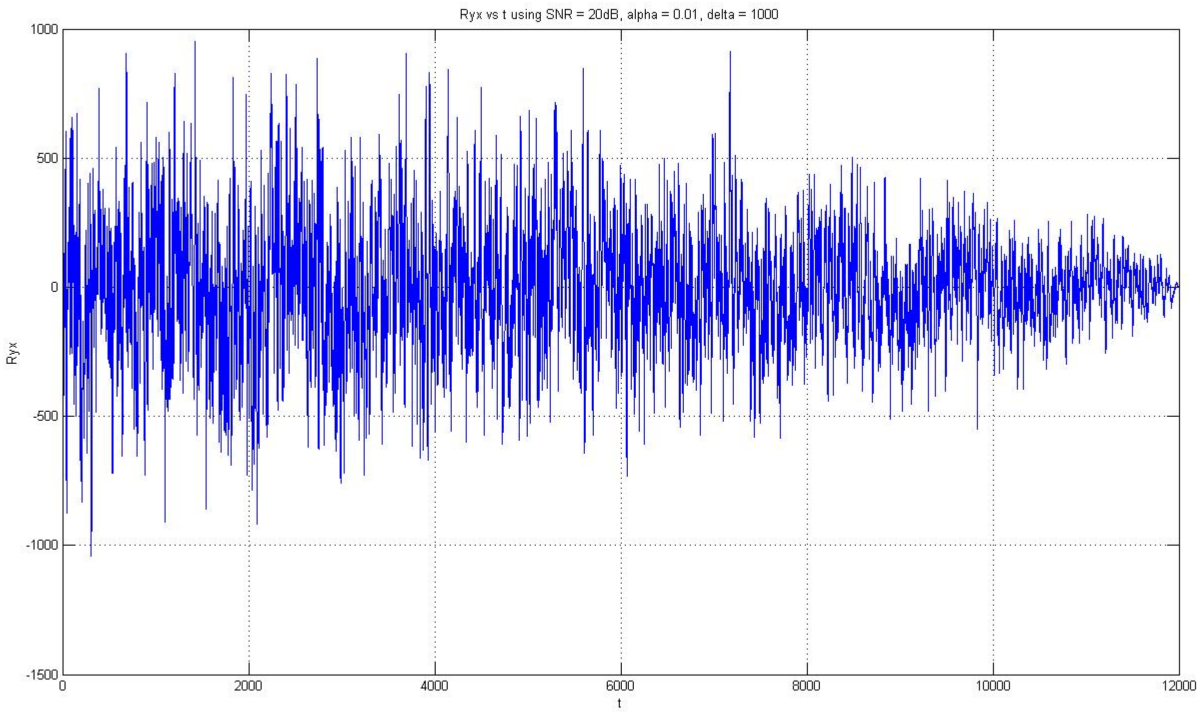
X(t) vs t
X(t)
t
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000



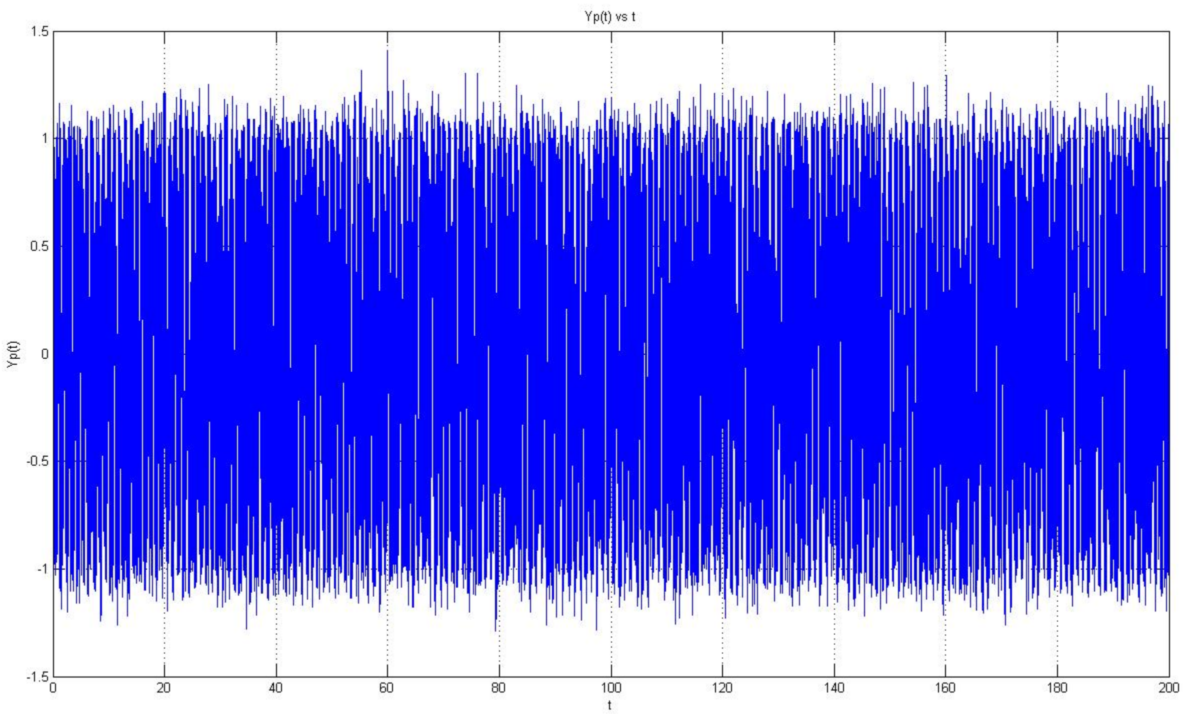
Y(t) vs t using SNR = 20dB, alpha = 0.01, delta = 1000
Y(t)
t
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
2000
4000
6000
8000
10000
12000



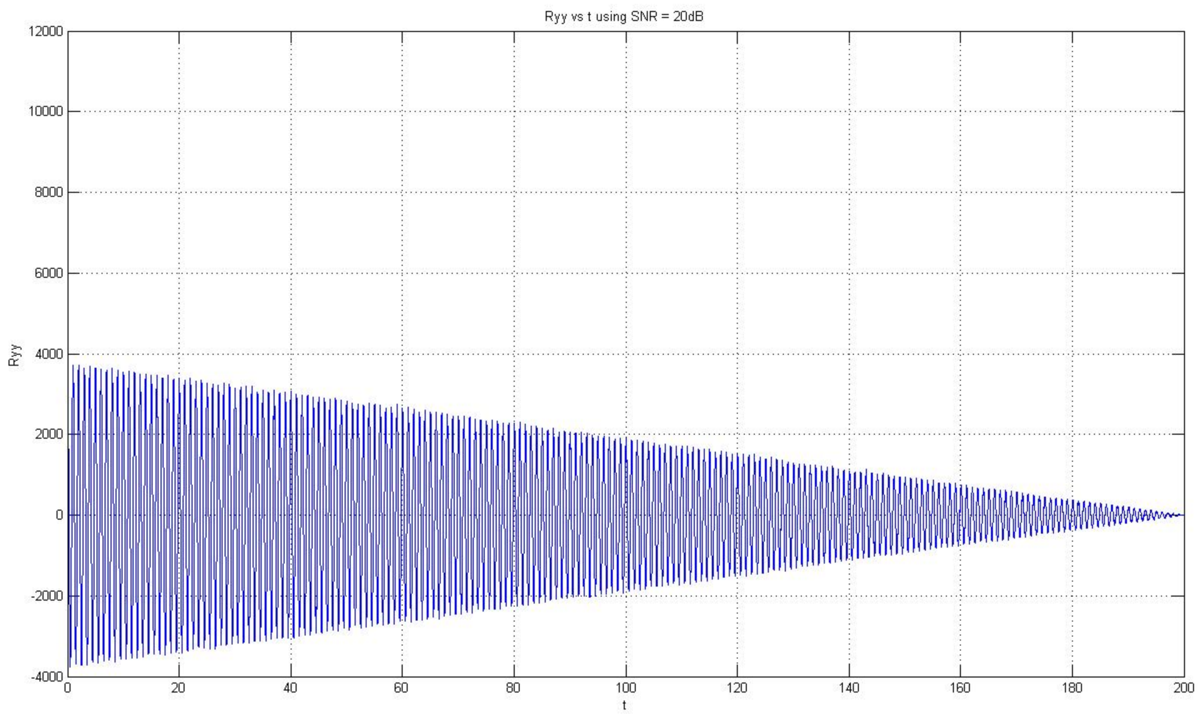
Ryx vs t using SNR = 20dB, alpha = 0.01, delta = 1000
120
100
80
60
40
20
0
-20
-40
Ryx
0
2000
4000
6000
8000
10000
12000
t



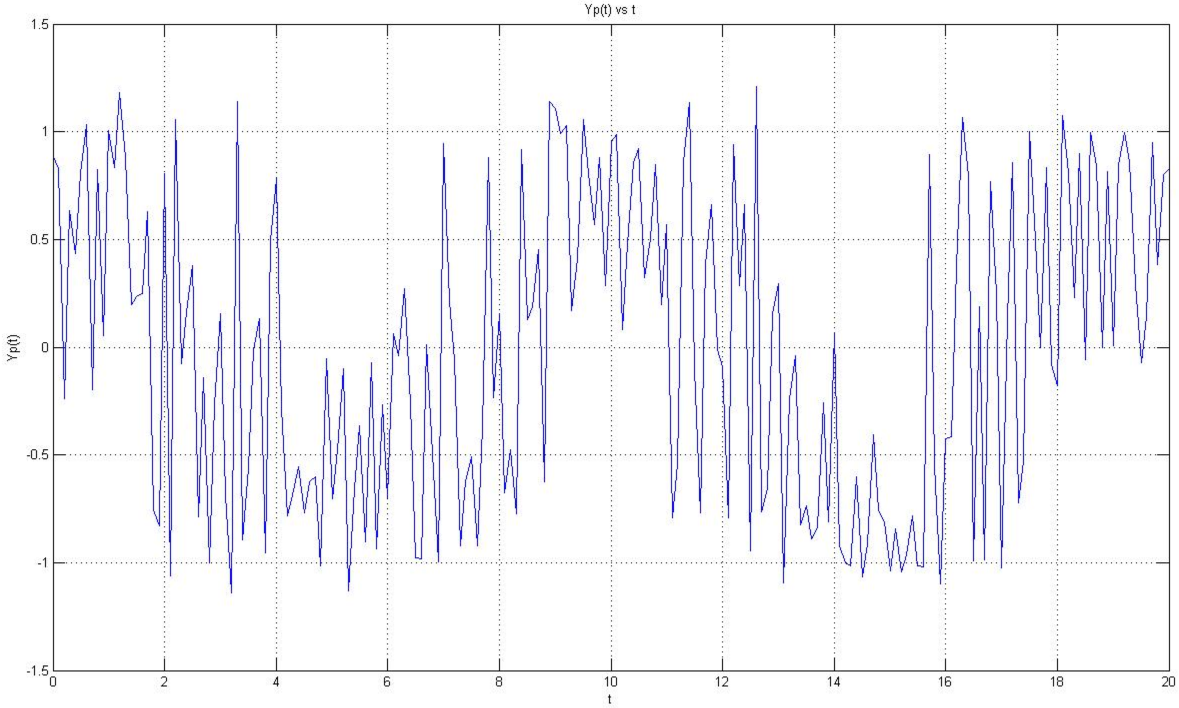
Ryx vs t using SNR = 20dB, alpha = 0.01, delta = 1000
1000
500
0
-500
-1000
-1500
Ryx
0
2000
4000
6000
8000
10000
12000
t



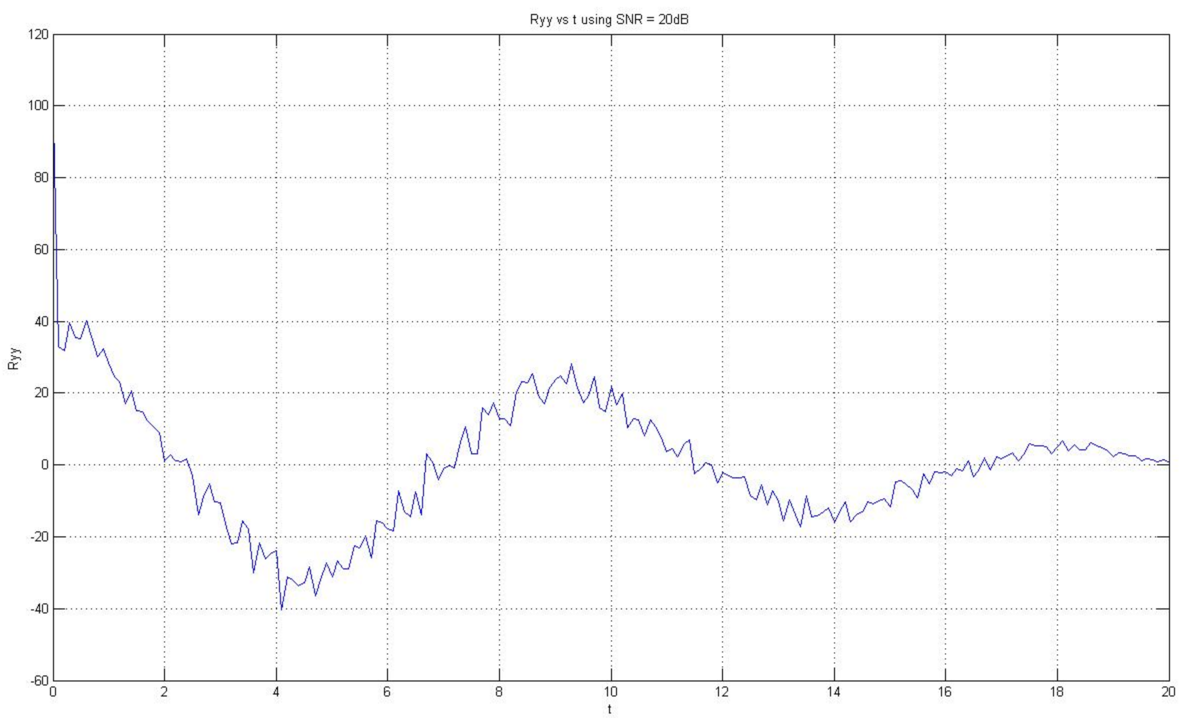
Yp(t) vs t
Yp(t)
t
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
140
160
180
200



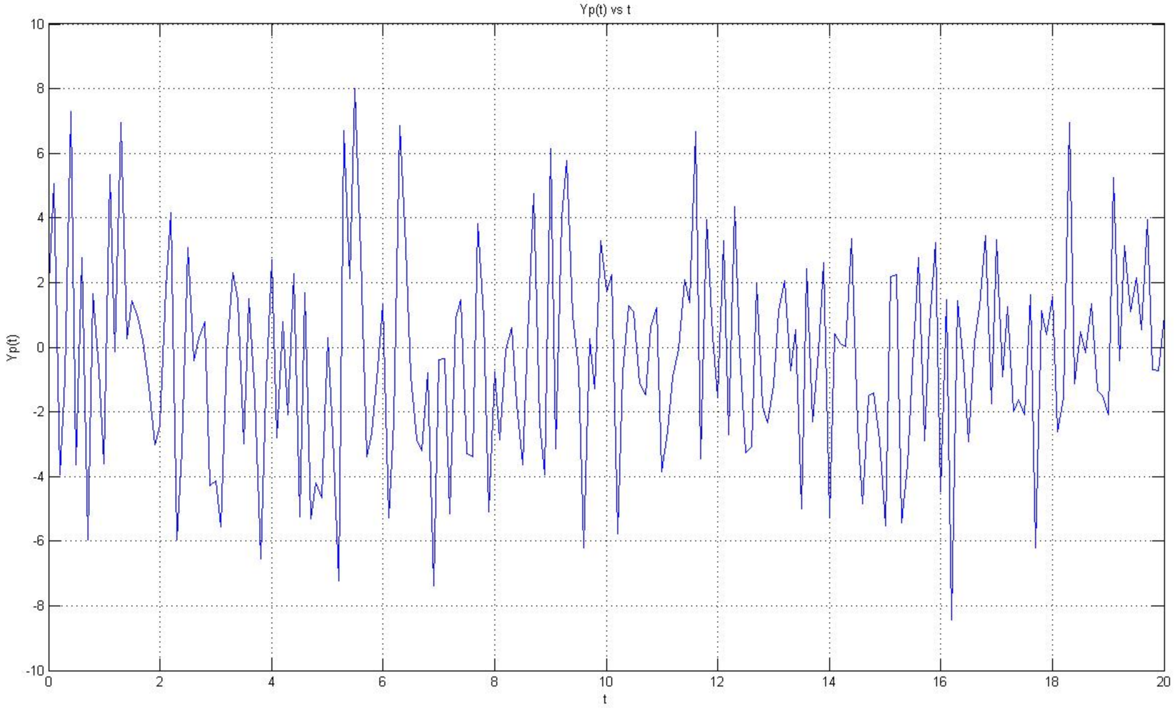
Ryy vs t using SNR = 20dB
Ryy
t
12000
10000
8000
6000
4000
2000
0
-2000
-4000
0
20
40
60
80
100
120
140
160
180
200



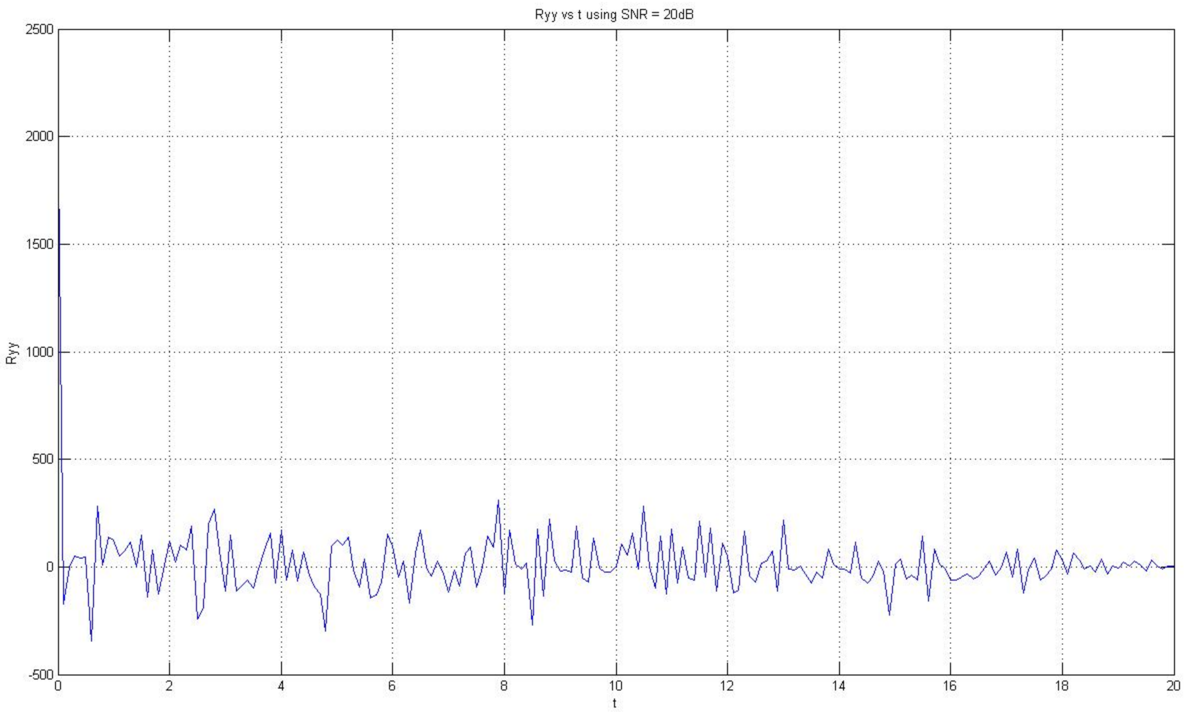
Yp(t) vs t
1.5
1
0.5
0
-0.5
-1
-1.5
Yp(t)
0
2
4
6
8
10
12
14
16
18
20
t

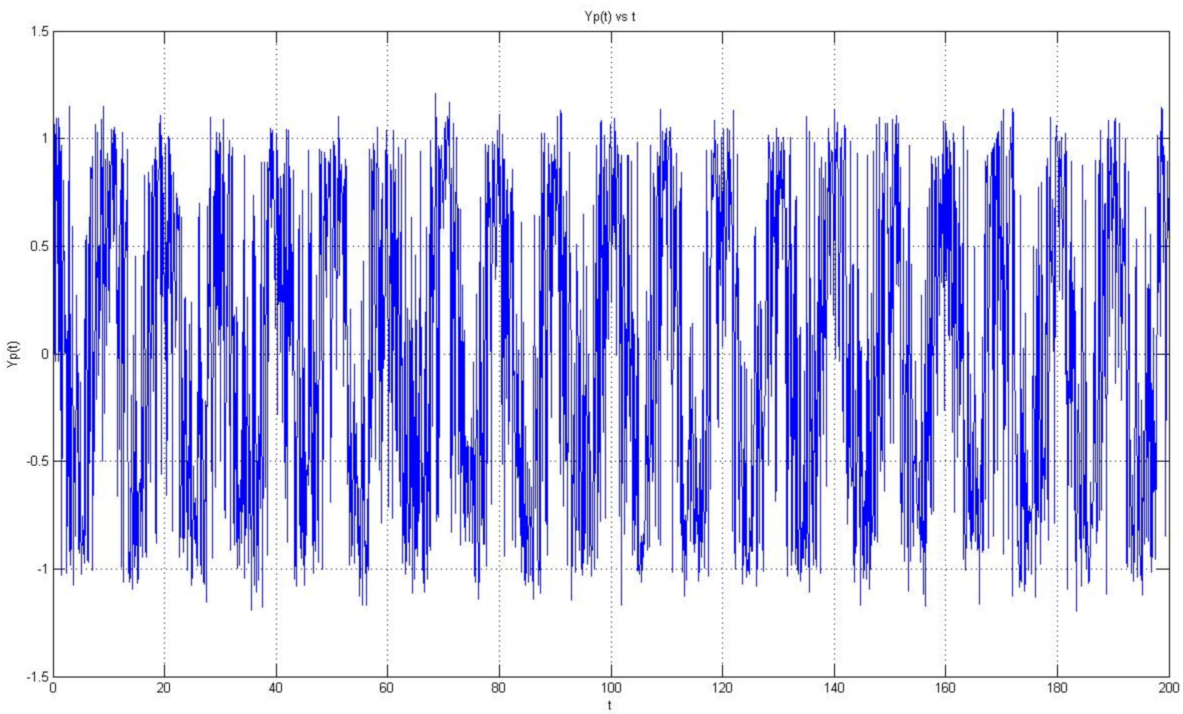


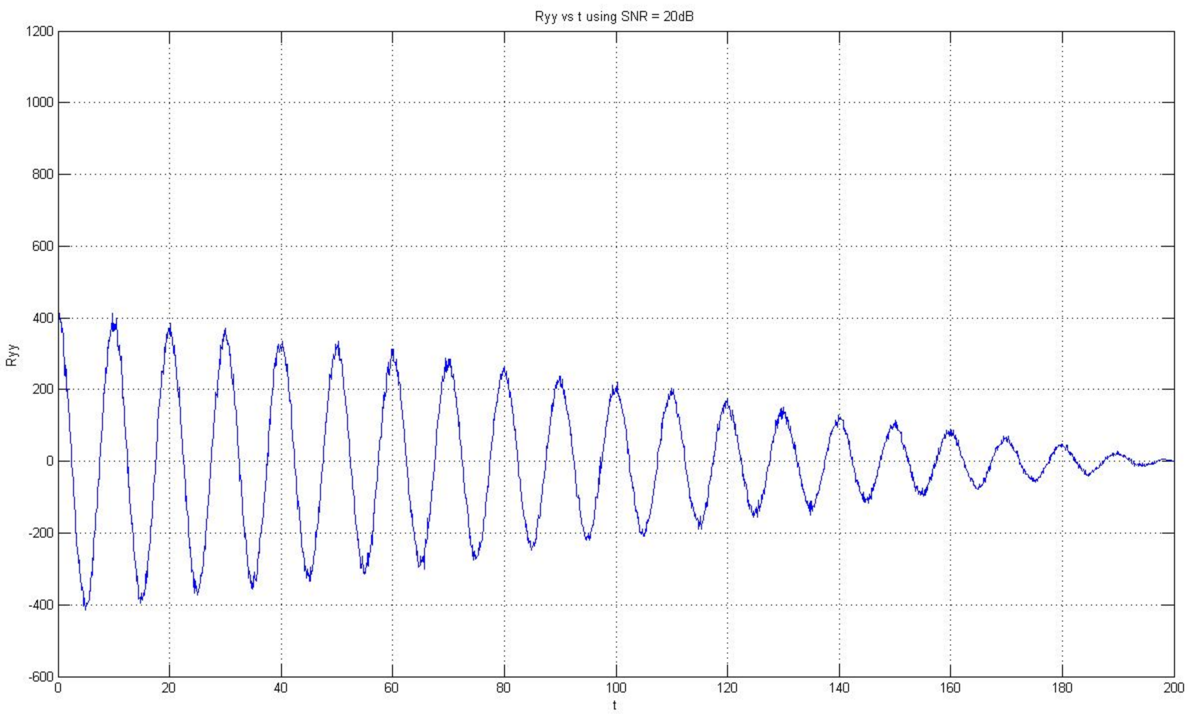
Ryy vs t using SNR = 20dB
120
100
80
60
40
20
0
-20
-40
-60
Ryy
0
2
4
6
8
10
12
14
16
18
20
t



Yp(t) vs t
10
8
6
4
2
0
-2
-4
-6
-8
-10
Yp(t)
0
2
4
6
8
10
12
14
16
18
20
t


Ryy vs t using SNR = 20dB
2500
2000
1500
1000
500
0
-500
Ryy
0
2
4
6
8
10
12
14
16
18
20
t


Yp(t) vs t
Yp(t)
t
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
140
160
180
200



Ryy vs t using SNR = 20dB
1200
1000
800
600
400
200
0
-200
-400
-600
Ryy
0
20
40
60
80
100
120
140
160
180
200
t