EN 2040

Random Signals and Processes

Simulation Assignment

Report

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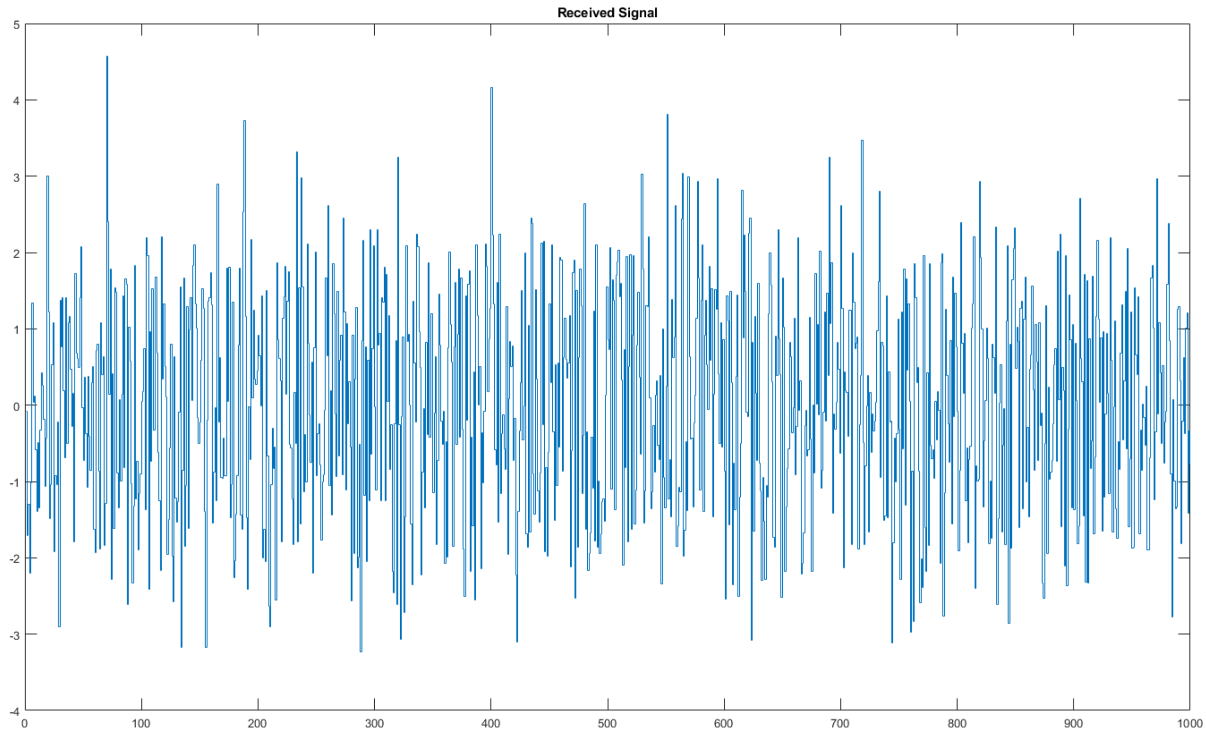
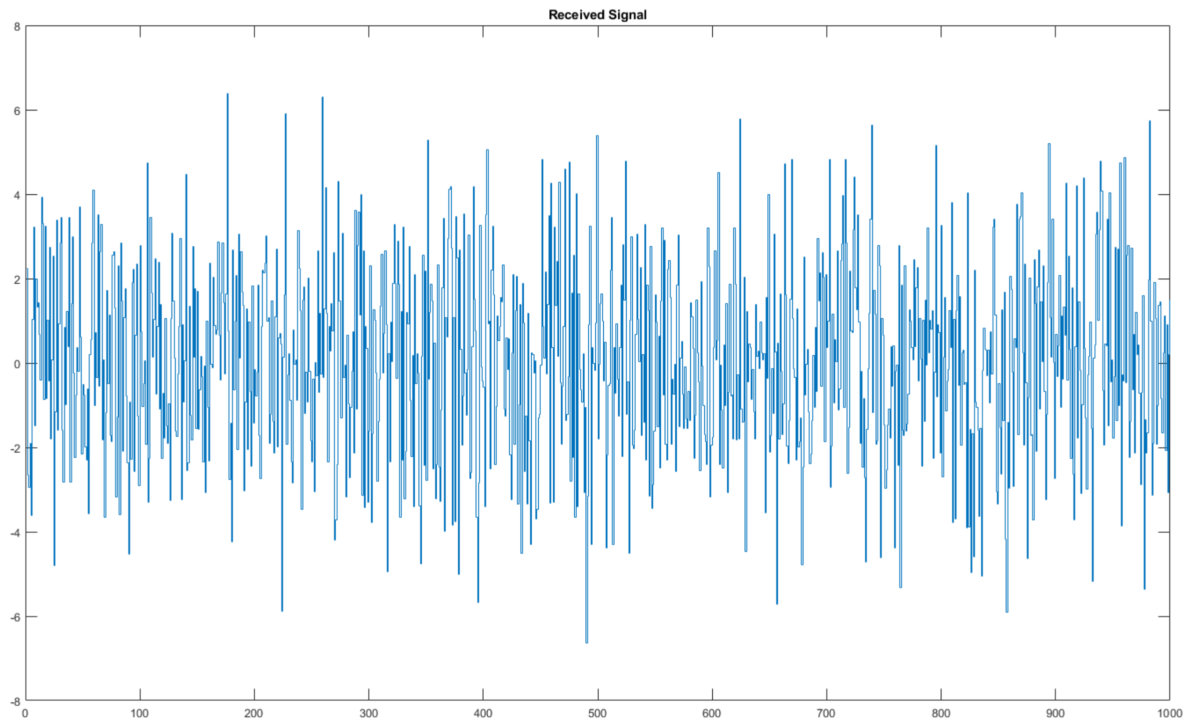
180205H

Q3)

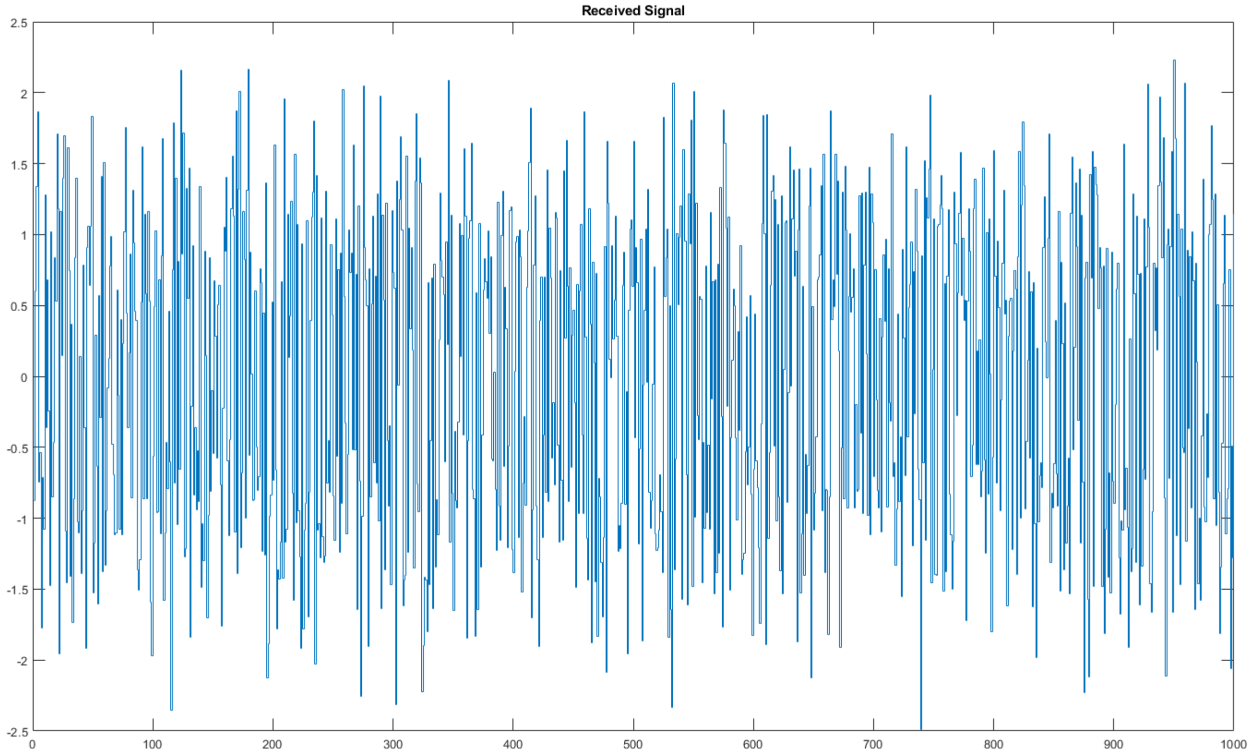
$$\sigma^2 = 1\,, \mu = 0$$



$$\sigma^2 = 4\,, \mu = 0$$

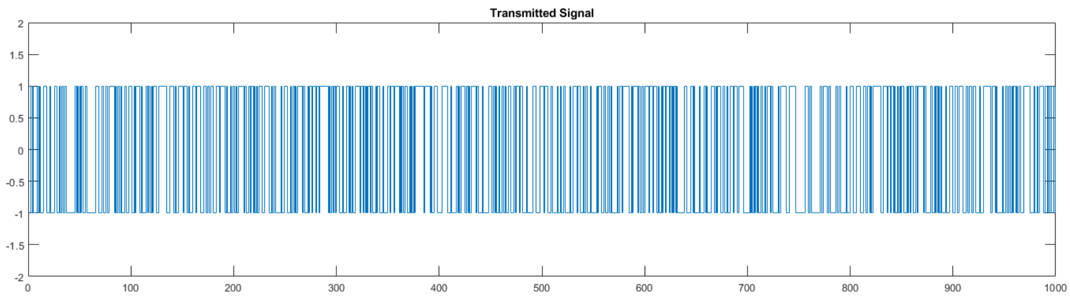


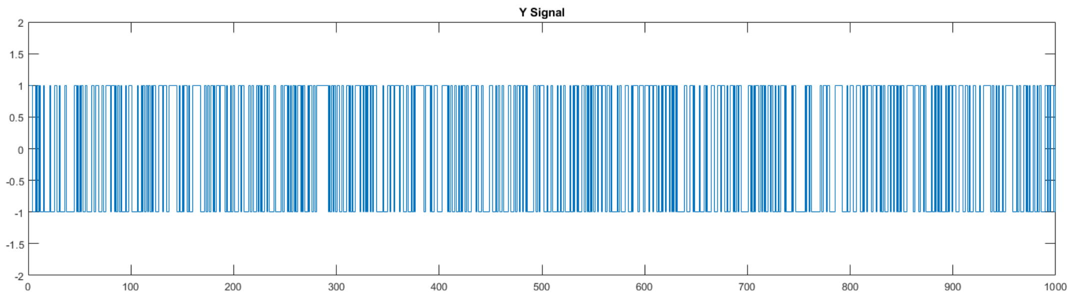
$$\sigma^2 = 0.5^2 , \mu = 0$$



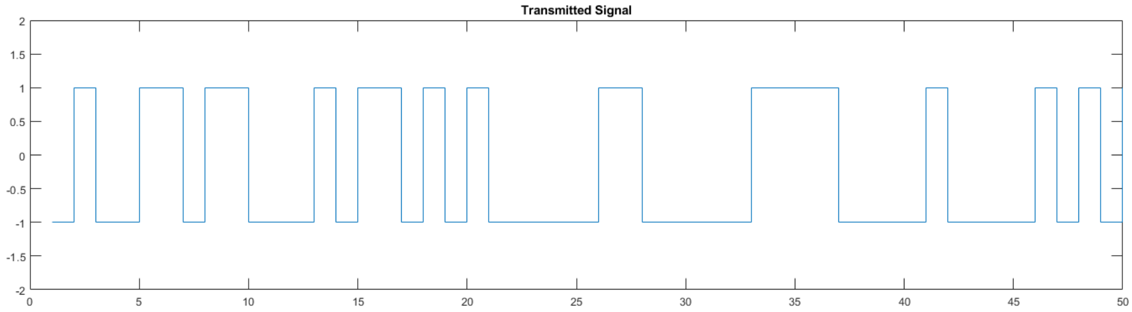
$$When\ \ \sigma\ increases\ the\ deviation\ from\ the\ original\ signal\ value\ increases$$

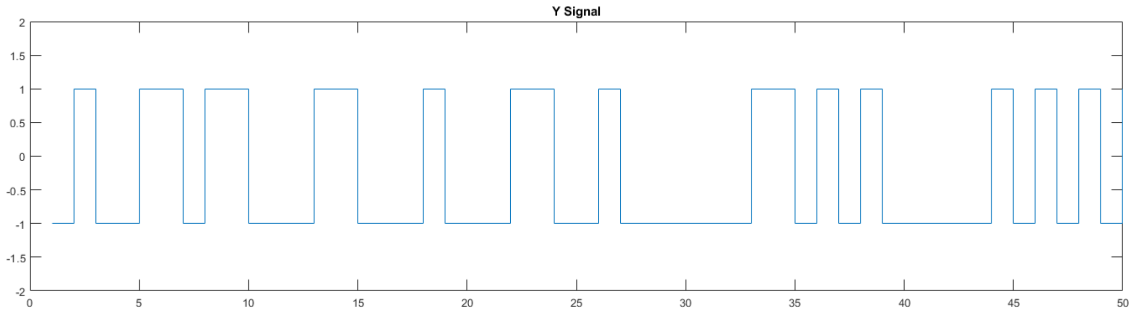
Q4)





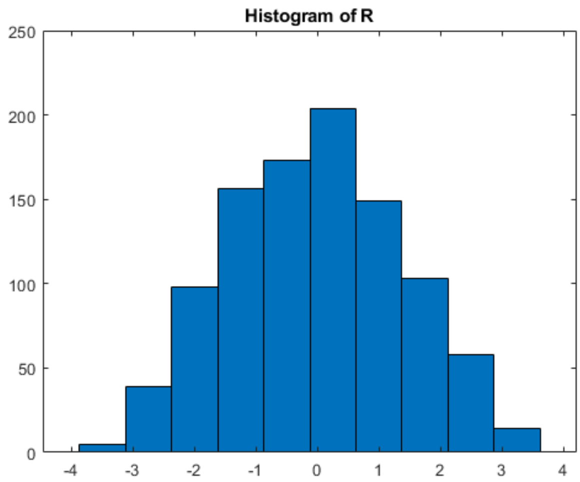
$There\ can\ be\ erros\ in\ decoding, as\ shown\ below$

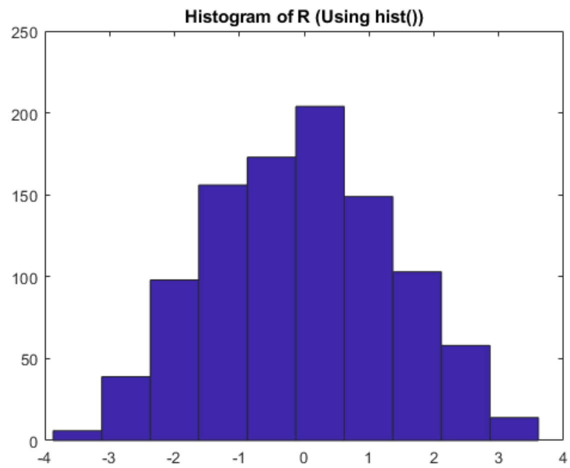




Q5)

$Comparison\ between\ builtin\ function\ and\ written\ function\ (no\ of\ bins = 10)$

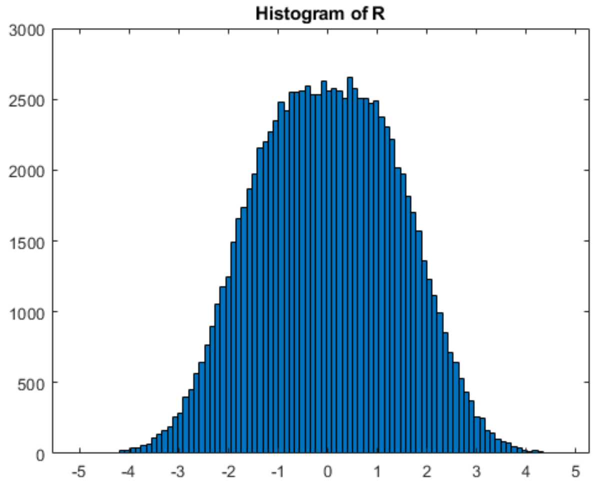


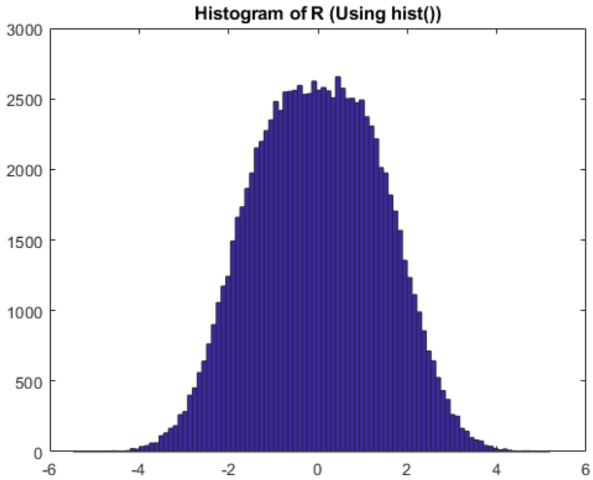


The histograms have a distant appearance of Gaussian distribution.

a)

$$Comparison\ between\ builtin\ function\ and\ written\ function\ (no\ of\ bins = 100)$$

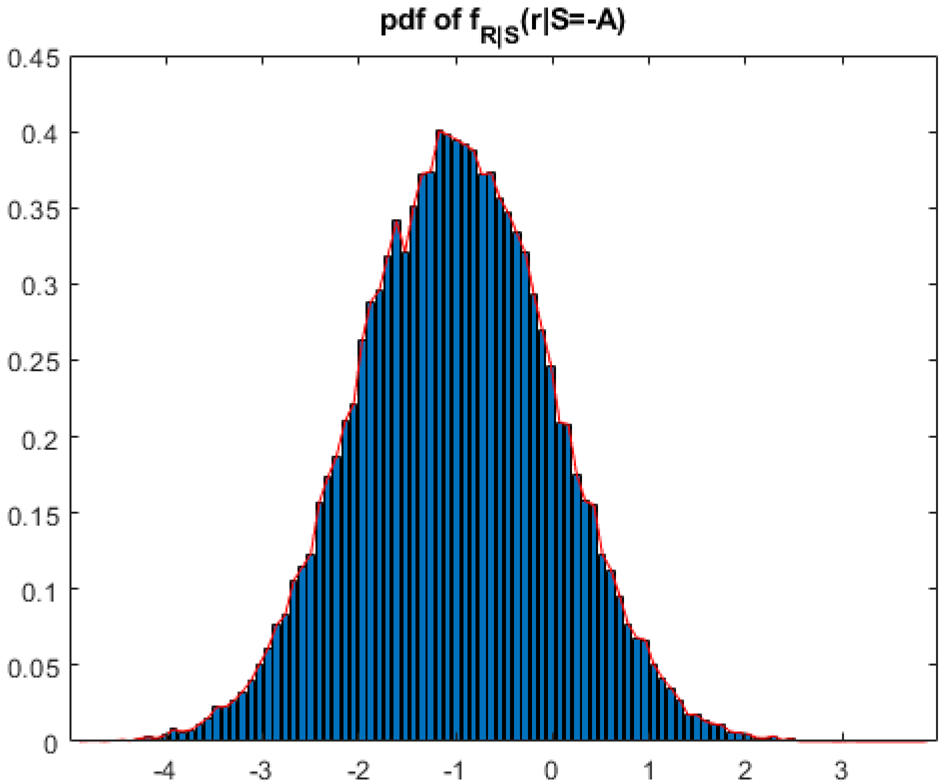




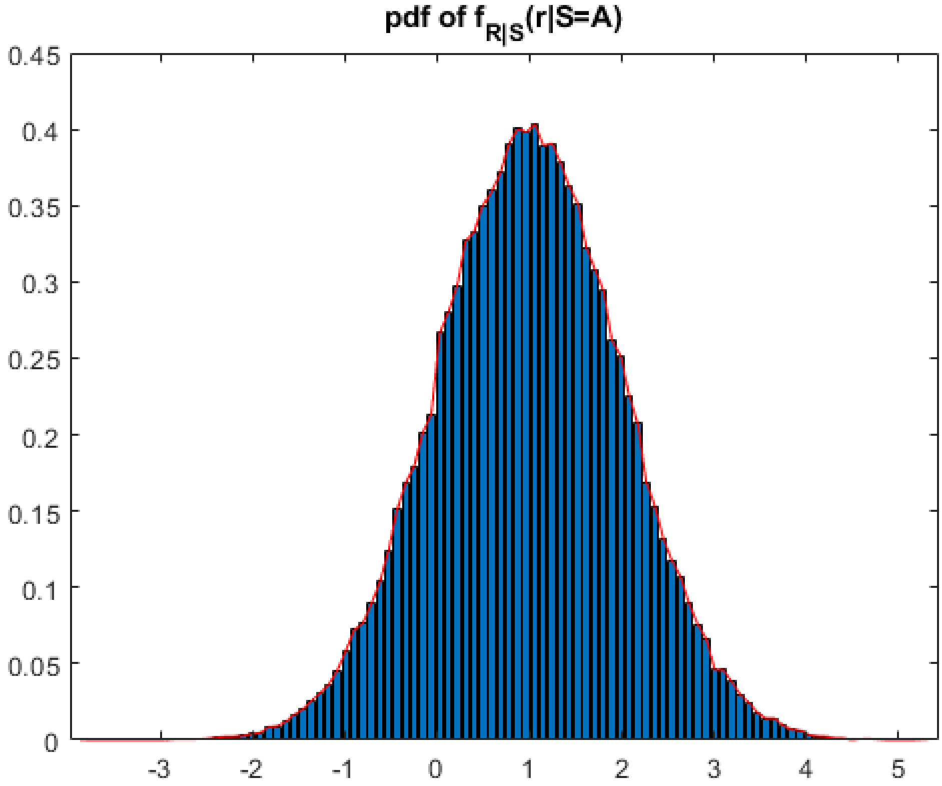
Upon increasing the no of bins, histograms have obtained a close look of Gaussian distribution.

b)

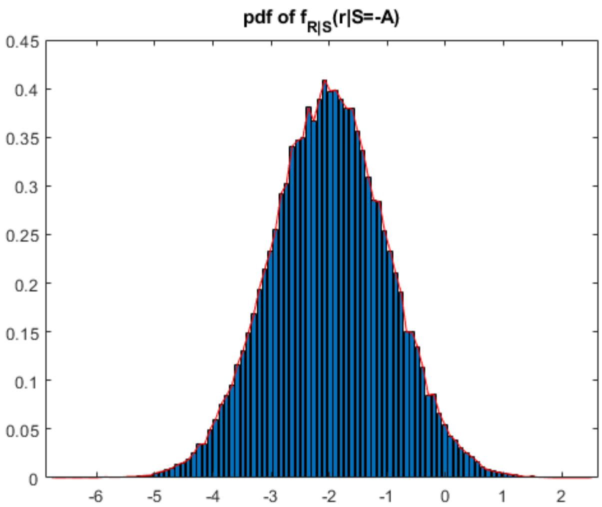
$$f_{R|S}(r|S=-A), A=1$$



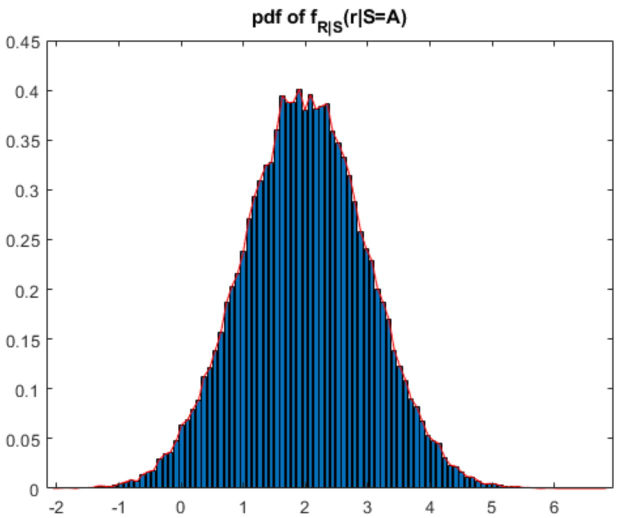
$f_{R|S}(r|S = A), A = 1$



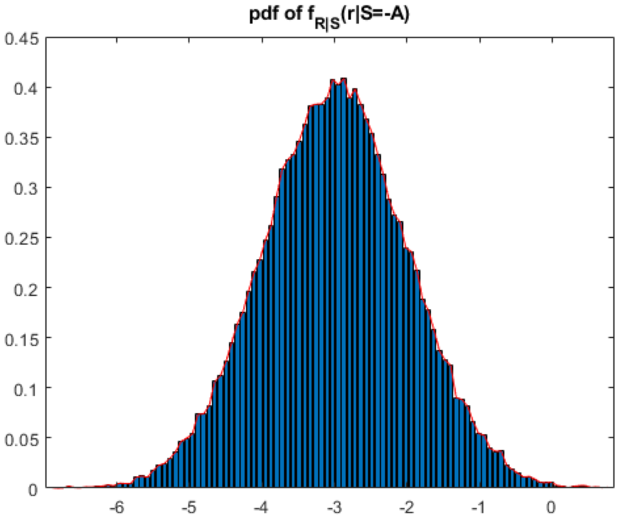
$f_{R|S}(r|S = -A), A = 2$



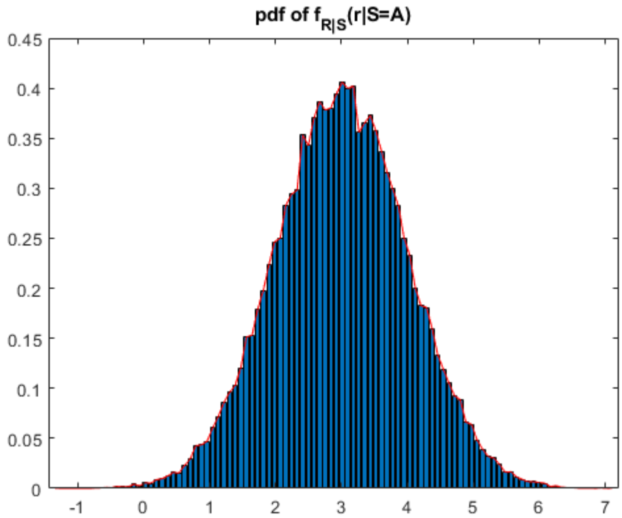
$f_{R|S}(r|S = A), A = 2$



$f_{R|S}(r|S = -A), A = 3$



$f_{R|S}(r|S = A), A = 3$



When A increases the pdfs deviates from its initial positions when A=1.

This is due to mean values of the pdfs is -A for $f_{R|S}(r|S = -A)$ and A for $f_{R|S}(r|S = A)$

c)

For the expected value,

$$E[X] = \sum_{i=1}^{N} x_i \, f_{x_i} \Delta x_i$$

Where,

$$f_{x_i} = frequency\ of\ each\ bin$$

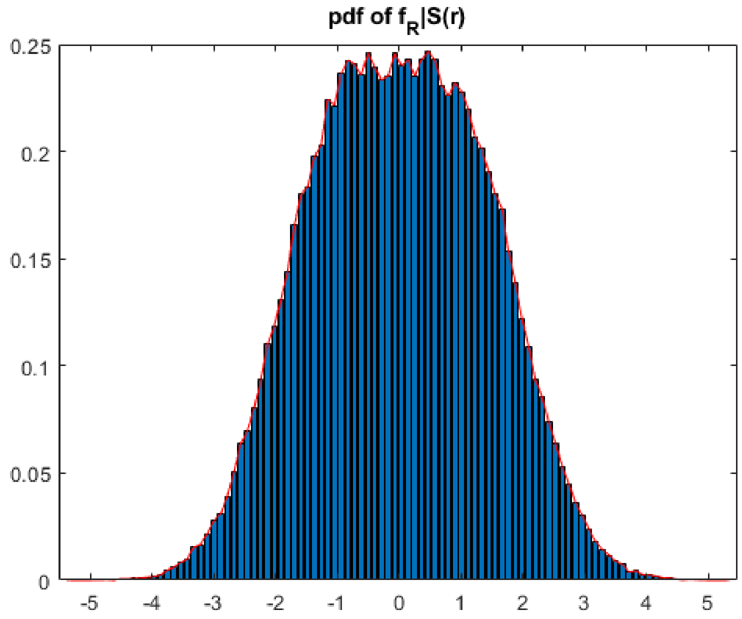
$$x_i = mid\ value\ of\ bin$$

$$\Delta x_i = width\ of\ bin$$

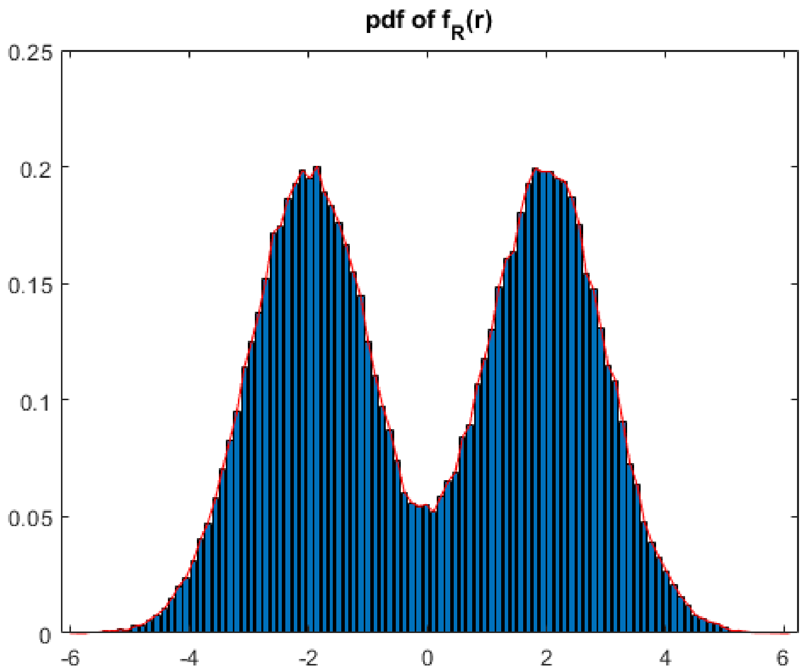
A	E [R|S = A]	E [R|S = -A]	E [R]
1	1.0025	-1.0017	0.003864
2	1.9976	-2.0006	-0.0012
3	3.0006	-3.0068	-0.0029

d)

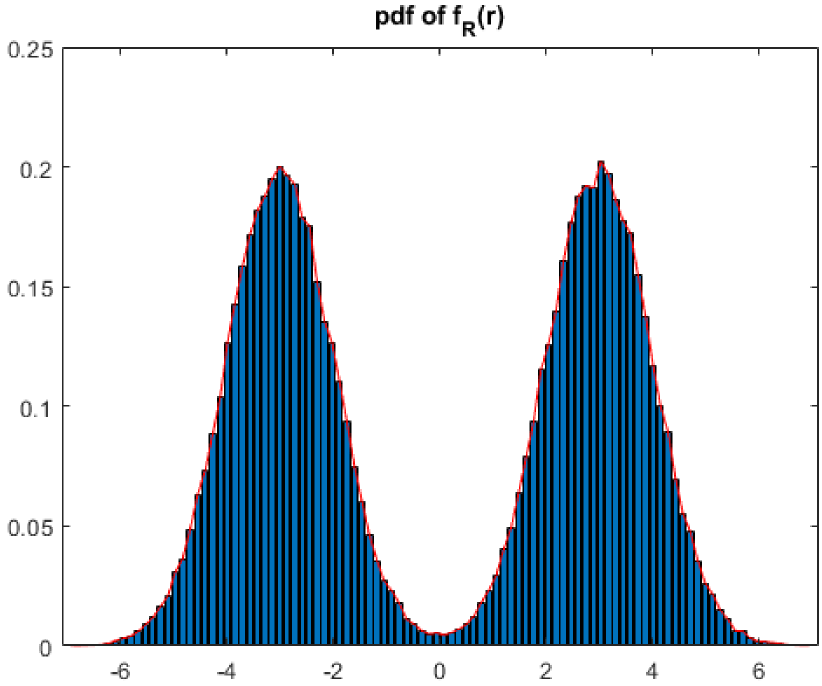
$f_R(r), A = 1$



$f_R(r), A = 2$



$f_R(r), A = 3$

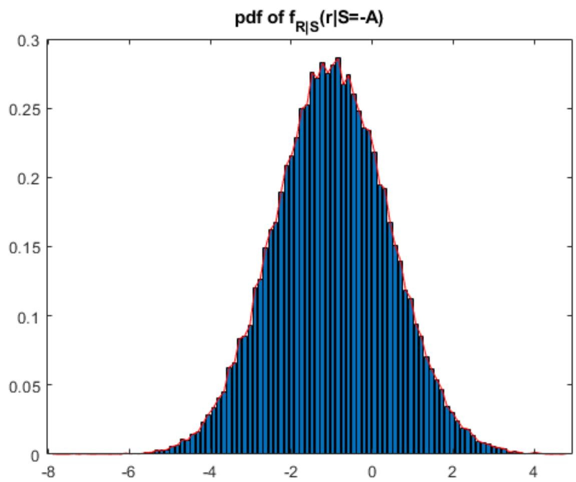


Q6)

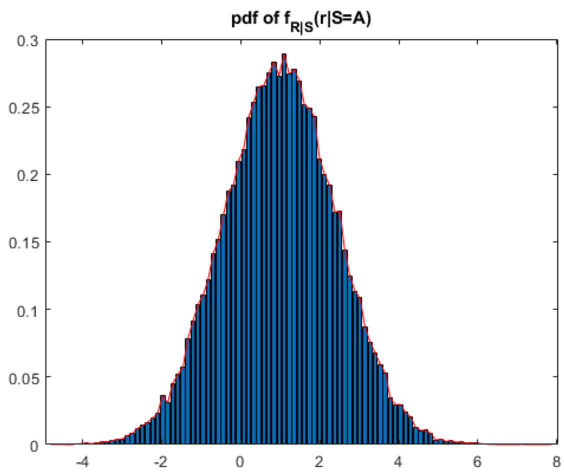
b)

$A = 1$

$f_{R|S}(r|S = -A)$

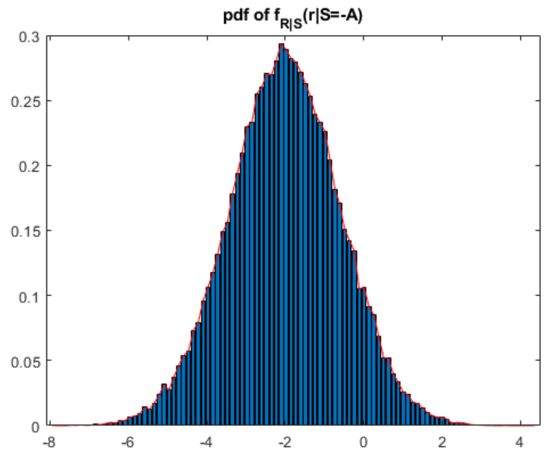


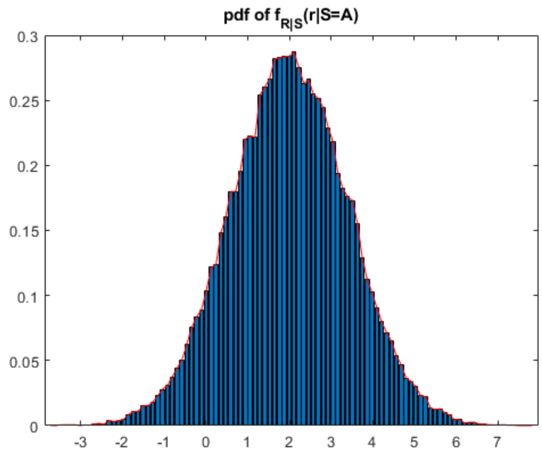
$f_{R|S}(r|S = A)$



$$A = 2$$

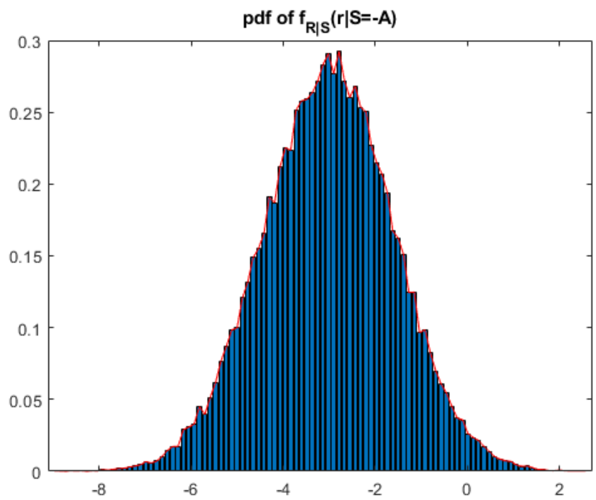
$f_{R|S}(r|S = -A)$ $\quad$ $f_{R|S}(r|S = A)$

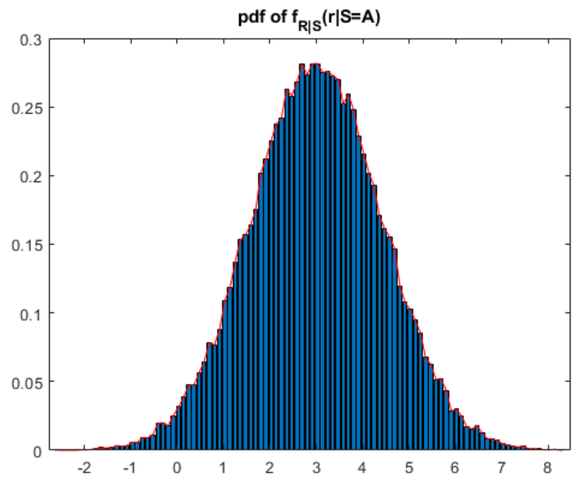




$$A = 3$$

$f_{R|S}(r|S = -A)$ $\quad$ $f_{R|S}(r|S = A)$



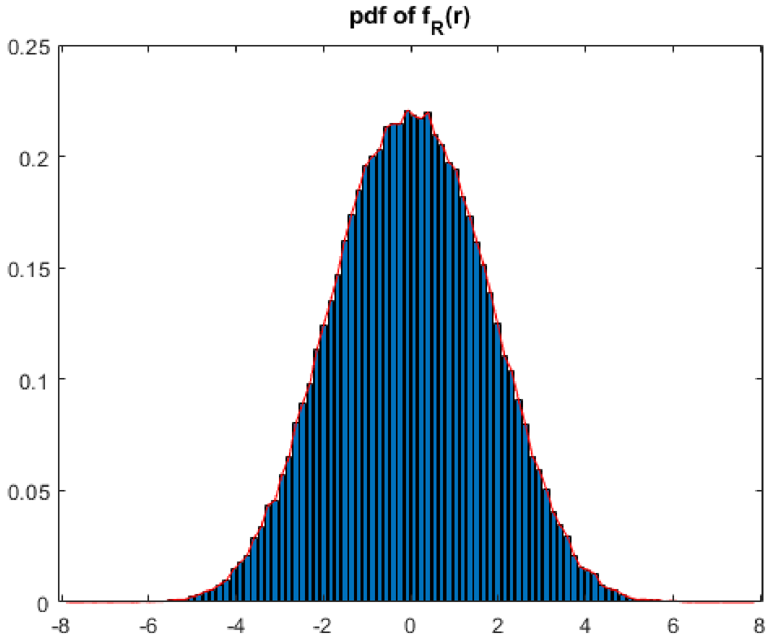


c)

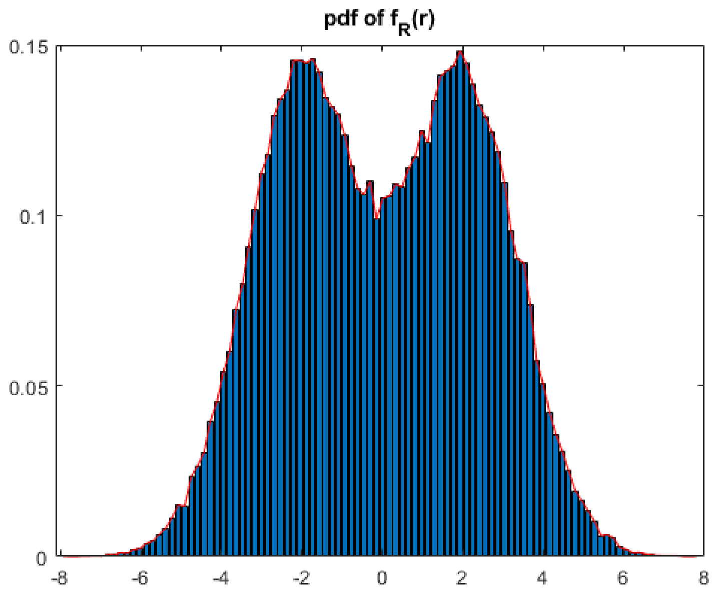
A	E [R | S = A]	E [R | S = -A]	E [R]
1	0.9965	-0.9965	-0.000091
2	2.0001	-2.0088	-0.0044
3	2.999	-3.0159	-0.0081

d)

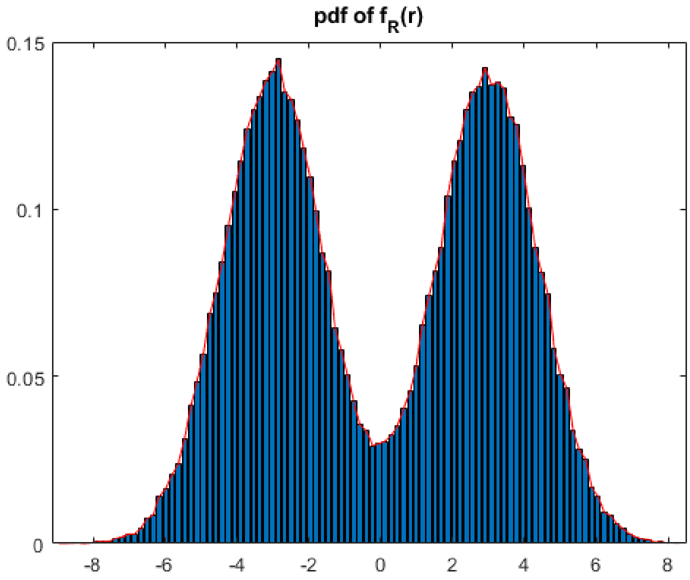
$f_R(r), A = 1$



$f_R(r), A = 2$



$f_R(r), A = 3$



When increasing A, the middle separation of $f_R(r)$ increases, but it is not quite dominant as without the interference (in Q5-d). This is due to interference another Gaussian random signal gets added to the Initial Signal which increased the variance of both $f_{R|S}(r|S = -A)$ and $f_{R|S}(r|S = -A)$.

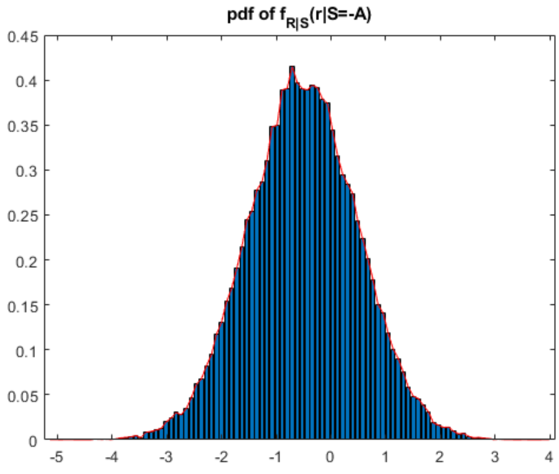
Upon calculating error it is noticed that Error has increased from 0.7965 to 0.9756

Q7)

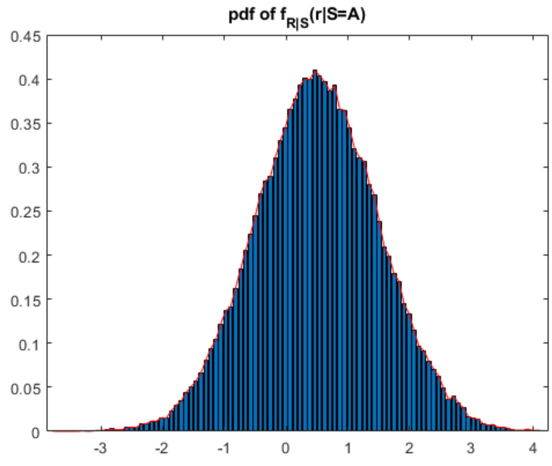
b)

$\alpha = 0.5, A = 1$

$f_{R|S}(r|S = -A)$

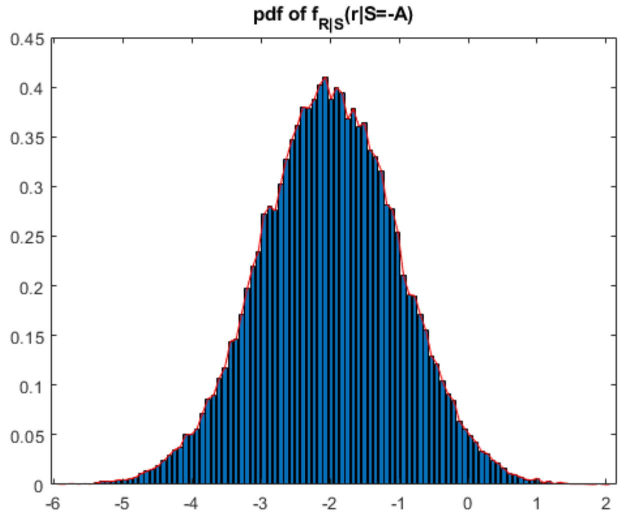


$f_{R|S}(r|S = A)$

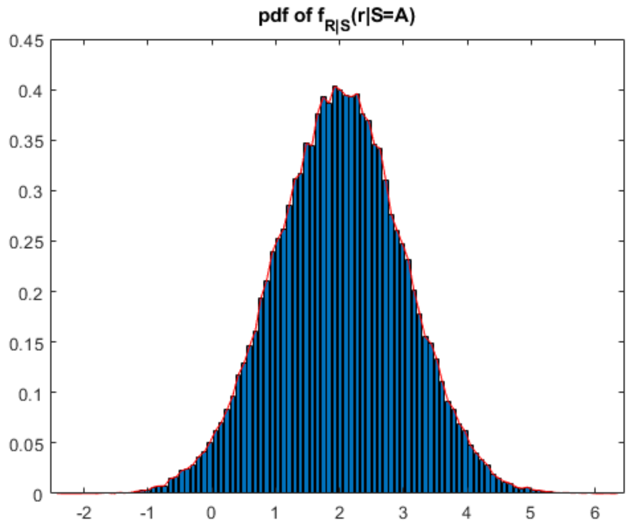


$\alpha = 2, A = 1$

$f_{R|S}(r|S = -A)$

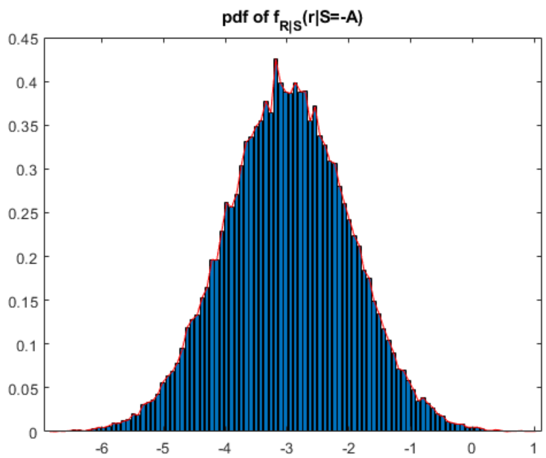


$f_{R|S}(r|S = A)$

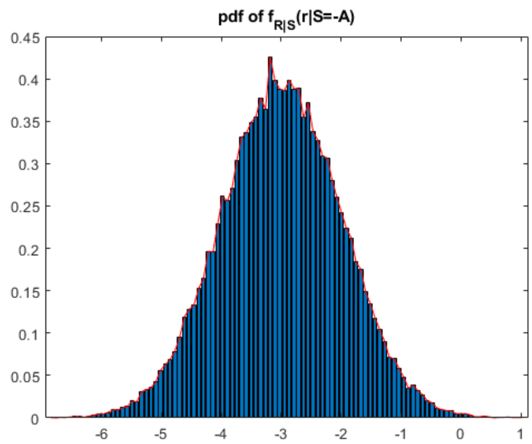


$\alpha = 3, A = 1$

$f_{R|S}(r|S = -A)$



$f_{R|S}(r|S = A)$

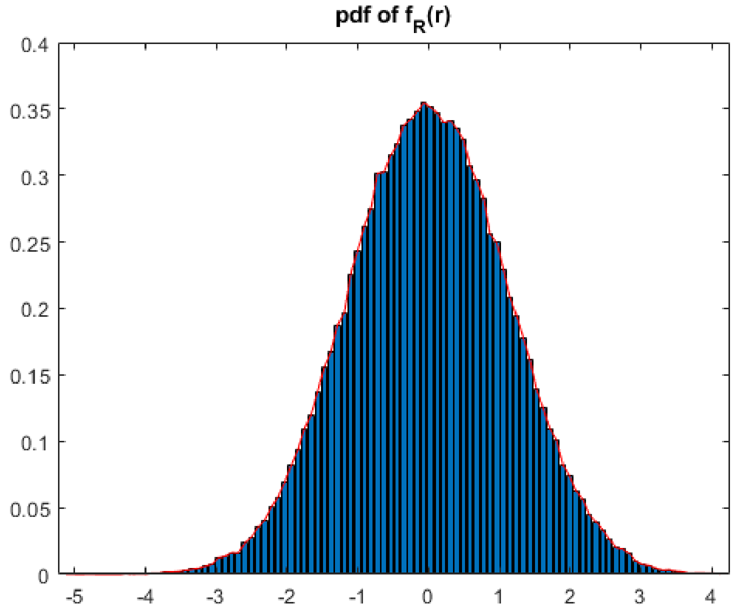


c) $A = 1$

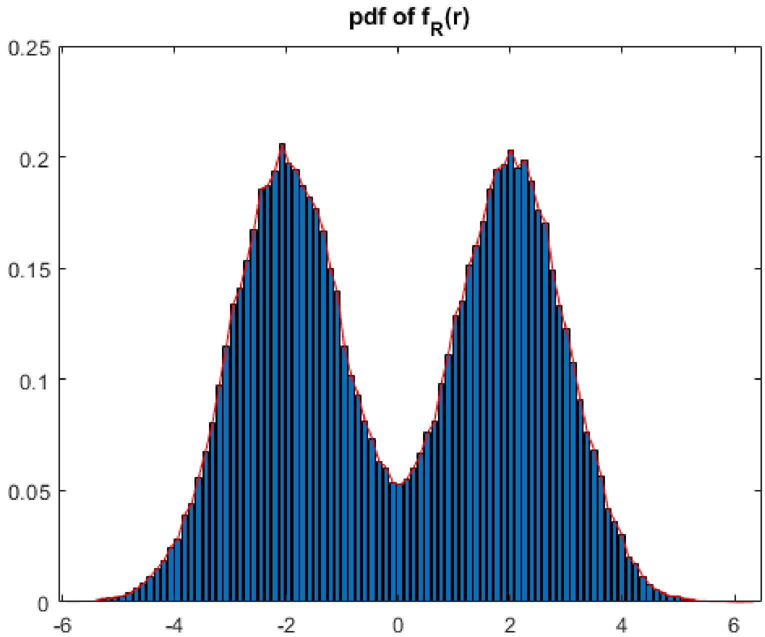
α	E [R|S = A]	E [R|S = -A]	E [R]
0.5	0.5011	-0.5090	-0.0038
2	1.9994	-2.0056	-0.0031
3	2.9899	-2.9972	-0.0035

d)

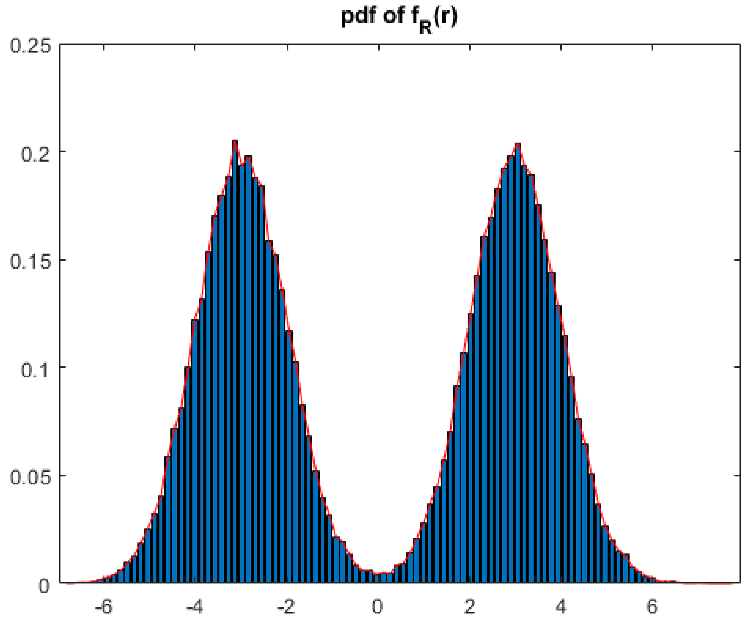
$f_R(r), A = 1, \alpha = 0.5$



$f_R(r), A = 1, \alpha = 2$



$f_R(r), A = 1, \alpha = 3$



When increasing α, the middle separation of $f_R(r)$ increases. This is due to mean values of the pdfs is - α A for $f_{R|S}(r|S = -A)$ and α A for $f_{R|S}(r|S = A)$.

Upon calculating error it is noticed that Error has decreased from 0.7965 to 0.0738 when the α increased to 3. Therefore Scaling reduces the error.

APPENDIX

```
L =100000;
D = zeros(1,L);
positions = randperm(L,L/2);
D(positions) = ones(1,L/2);

figure;
stairs(1:L,D);
axis([0 50 -0.5 1.5])
title("Binary Sequence");

%sequence of pulses
A = 1
S = -A*ones(1,L);
S(D==1)= A;

figure;
```

```
stairs(1:L,S);
axis([0 50 -1*A-1 A+1])
title("Transmitted Signal");

% AWGN
mean = 0;
sigma = 1;
N = mean + sigma*randn(1,L);
R = S + N;

%Interference
meanI = 0;
sigmaI = 1;
I = meanI + sigmaI*randn(1,L);
%R = S + N + I;

%Scaling
alpha=3
%R = alpha*S + N;

figure;
stairs(1:L,R);
%axis([0 L -1.5*A 1.5*A])
title("Received Signal");

%generating Y sequence
threshold = 0;
Y = -A*ones(1,L);
Y(R>threshold)=A;

figure;
subplot(2,1,1);
stairs([1:L],S);
axis([0 50 -1*A-1 A+1])
title("Transmitted Signal");

subplot(2,1,2);
stairs([1:L],Y);
axis([0 50 -1*A-1 A+1])
title("Y Signal");


%Error rate
Error = sqrt(sum((S-Y).^2)/L)

bin_no=100;%No of bins



R_max = max(R);
R_min = min(R);
width = (R_max-R_min)/bin_no;
bin_limits = R_min:width:R_max;

%histogram calclation
bins_centers = R_min+width/2:width:R_max-width/2;
frequency= zeros(1,bin_no);
for i=1:bin_no
    for j =1:L
        if (R(j)<=bin_limits(i+1)) && (R(j)>bin_limits(i))
            frequency(i)=frequency(i)+1;
        end
    end
end

figure;
```

```
bar(bins_centers,frequency,1);
title("Histogram of R");

figure;
hist(R,bin_no);
title("Histogram of R (Using hist())");


%f_R|S(r|S=A)
r_ifSA = R(S==A); %S = A
R_max1 = max(r_ifSA);
R_min1 = min(r_ifSA);
widthSA = (R_max1-R_min1)/bin_no;
[y1,x1] = hist(r_ifSA,bin_no);
prob1 = y1/(length(r_ifSA)*widthSA);
figure;
bar(x1,prob1);
hold on;
plot(x1,prob1,'r');
title("pdf of f_{R|S}(r|S=A)");

%f_R|S(r|S=-A)
r_ifS_A = R(S==-A); %S = -A
R_max1 = max(r_ifS_A);
R_min1 = min(r_ifS_A);
widthS_A = (R_max1-R_min1)/bin_no;
[y2,x2] = hist(r_ifS_A,bin_no);
prob2 = y2/(length(r_ifS_A)*widthS_A);
figure;
bar(x2,prob2);
hold on;
plot(x2,prob2,'r');
title("pdf of f_{R|S}(r|S=-A)");

%f_R(r)
R_max = max(R);
R_min = min(R);
width= (R_max-R_min)/bin_no;
[y,x] = hist(R,bin_no);
probR = y/(length(R)*width);
figure;
bar(x,probR);
hold on;
plot(x,probR,'r');
title("pdf of f_R(r)");

%E[R|S=A]
E_R_ifSA = 0;
for i1 = 1:bin_no
    E_R_ifSA = E_R_ifSA + x1(i1)*prob1(i1)*widthSA;
end
E_R_ifSA

%E[R|S=-A]
E_R_ifS_A = 0;
for i2 = 1:bin_no
    E_R_ifS_A = E_R_ifS_A + x2(i2)*prob2(i2)*widthS_A;
end
E_R_ifS_A

%E[R]
E_R = 0;
for i3 = 1:bin_no
E_R = E_R + (x(i3)*probR(i3)*width);
end
E_R
```