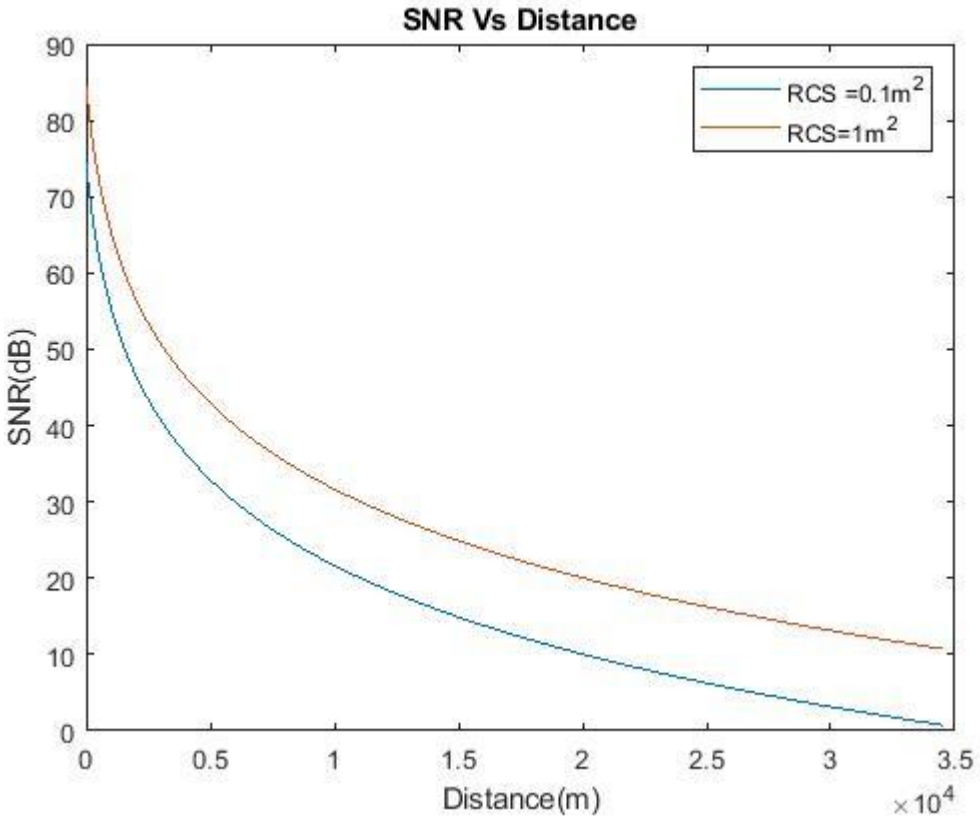
Received SNR level as a function of range



Maximum detectable range of the system for the different considered targets.

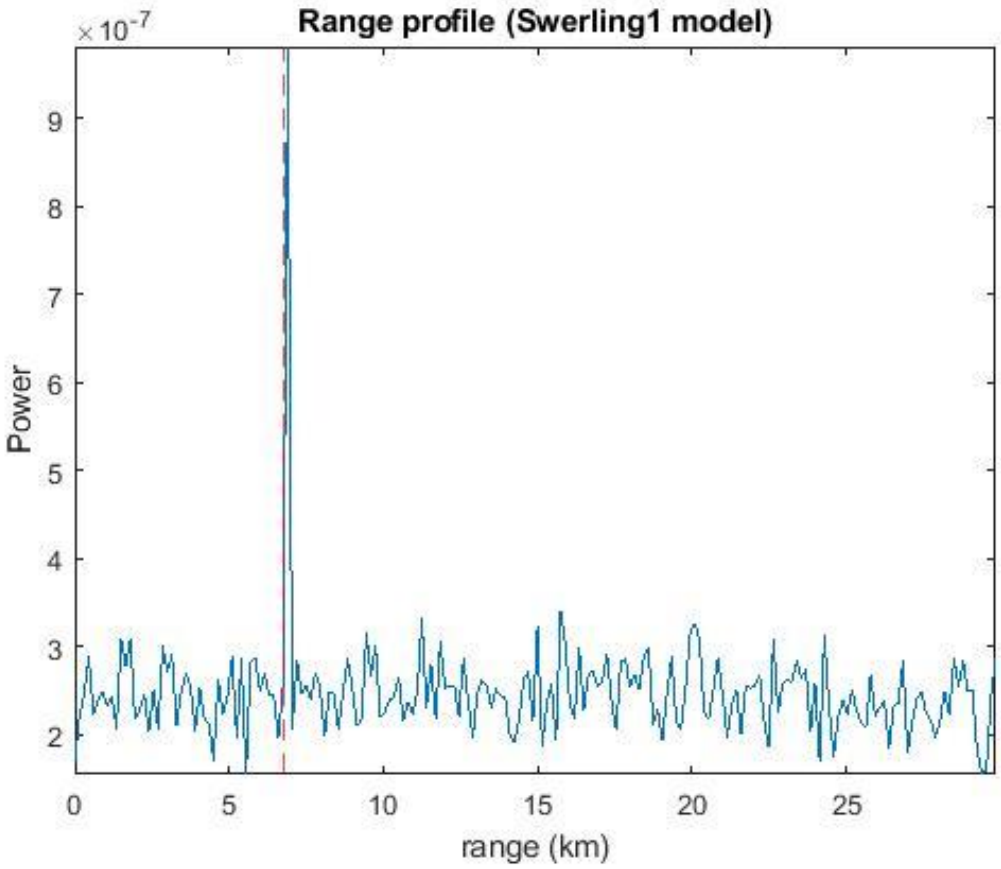
tgtrng1 = 1.4555e+04 = 14.55 km

tgtrng2 = 2.5883e+04 = 25.88 km

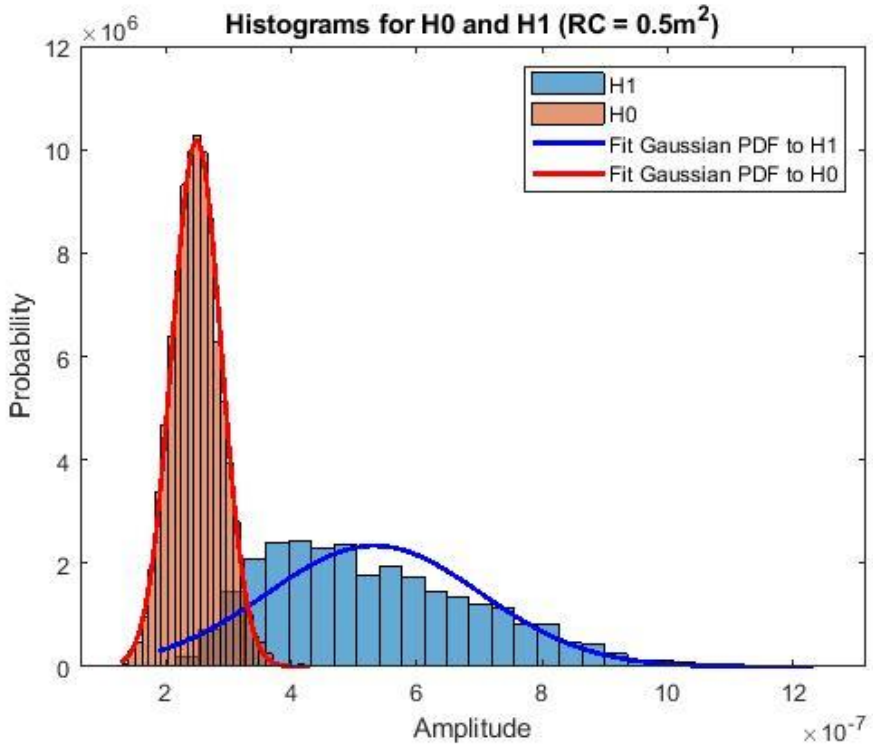
Obtain the range profile of this scenario for multiple iterations. What is the effect of the Swerling model?

If the target velocity is low compared to the observation time, then the target can be non-moving. Scanning radar systems are fast-acting devices that send out a signal that sweeps past the target in a short period of time. The motion of the target is only seen from scan-to-scan, not from within a scan.

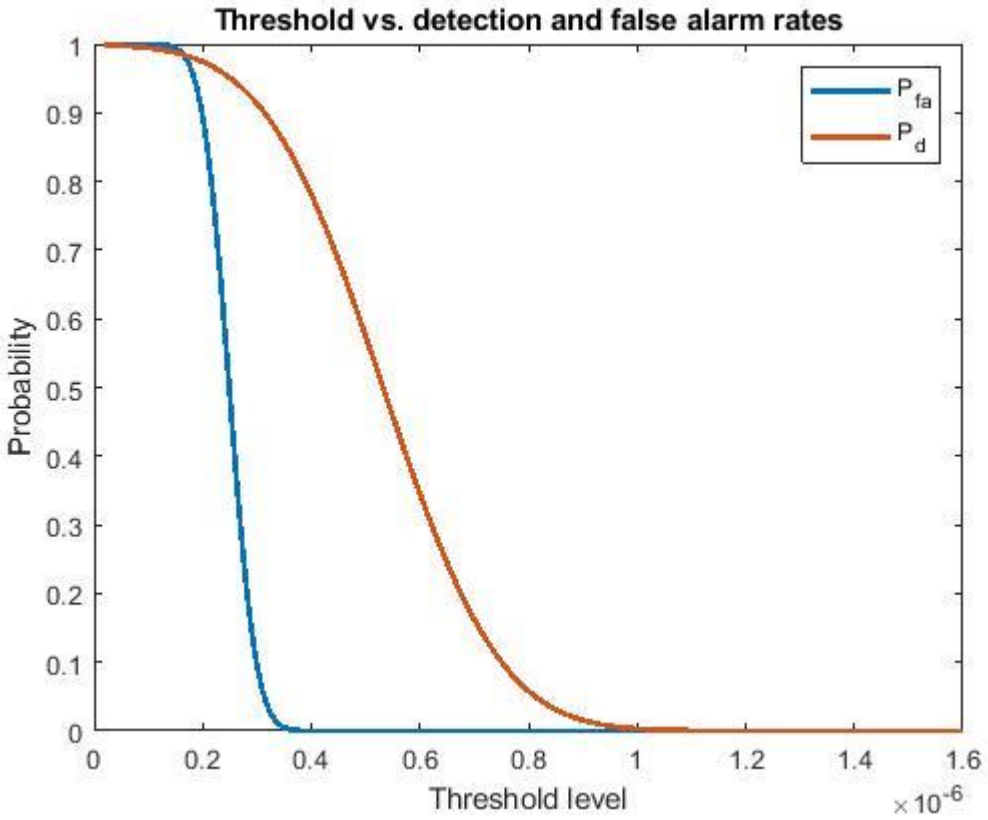
In Swerling model, target whose magnitude of the backscattered signal is relatively constant during the dwell time. It varies according to a Chi-square probability density function with two degrees of freedom (m = 1). The radar cross section is constant from pulse-to-pulse but varies independently from scan to scan. The density of probability of the RCS is given by the Rayleigh-Function.



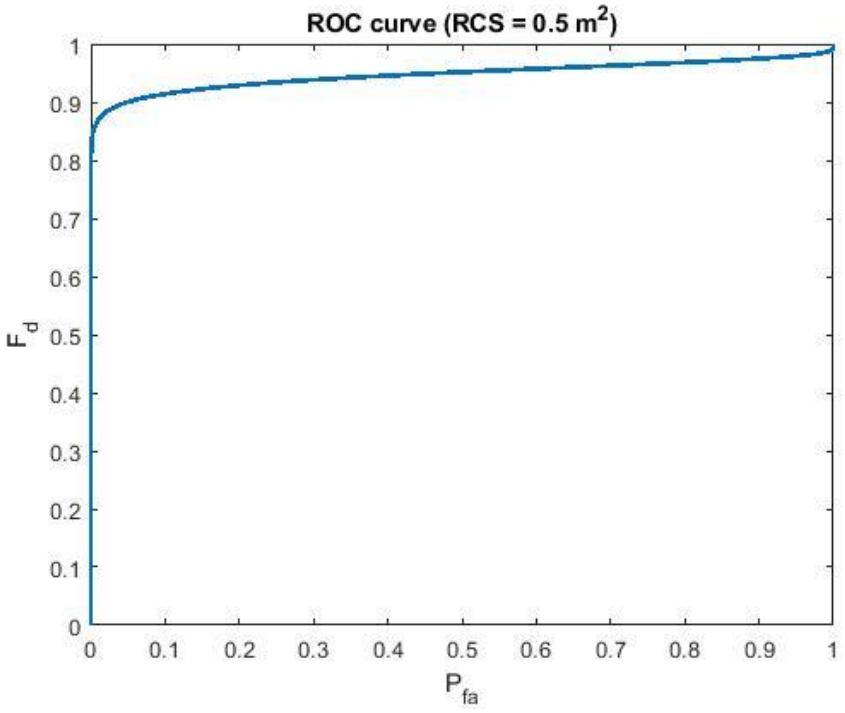
Obtain the histograms for the two possible hypotheses.



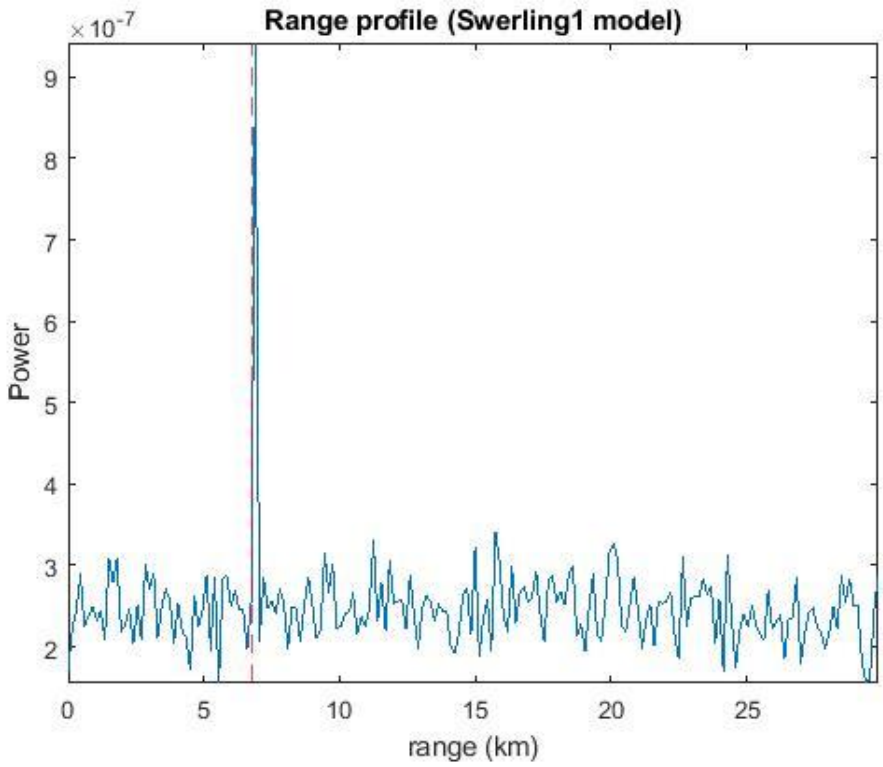
Analyse how the threshold level affects to the false alarm and detection probabilities of the system

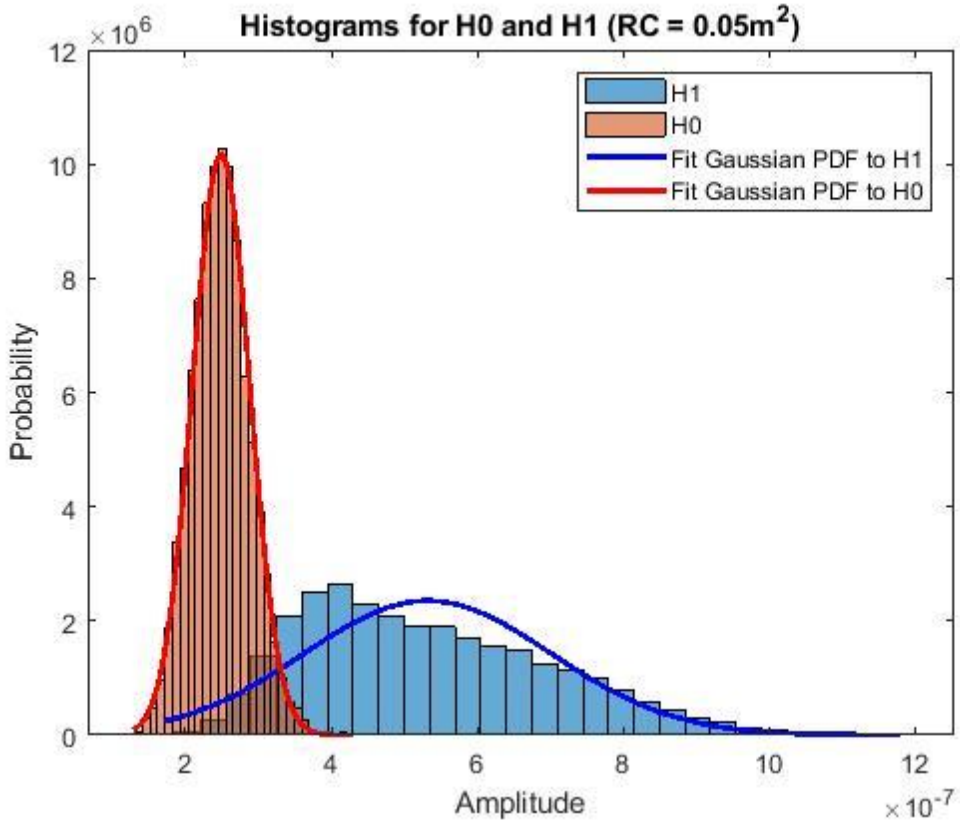


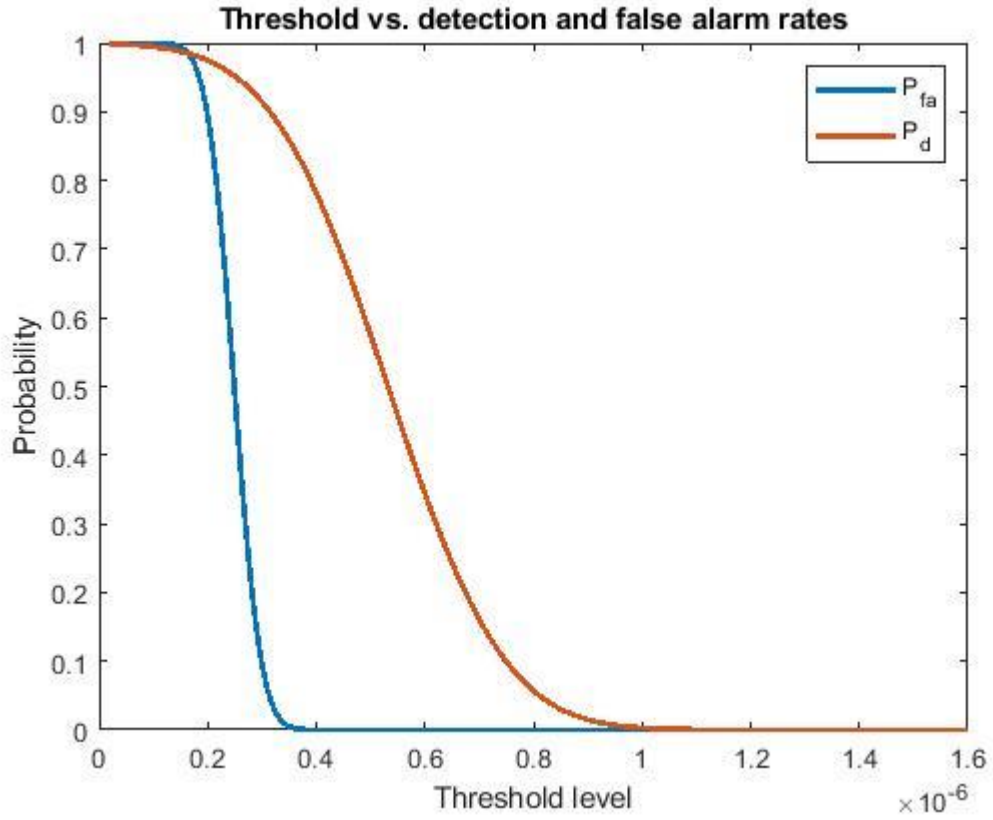
Obtain the Receiver Operating Characteristics (ROC) curve (Pd vs. Pfa)

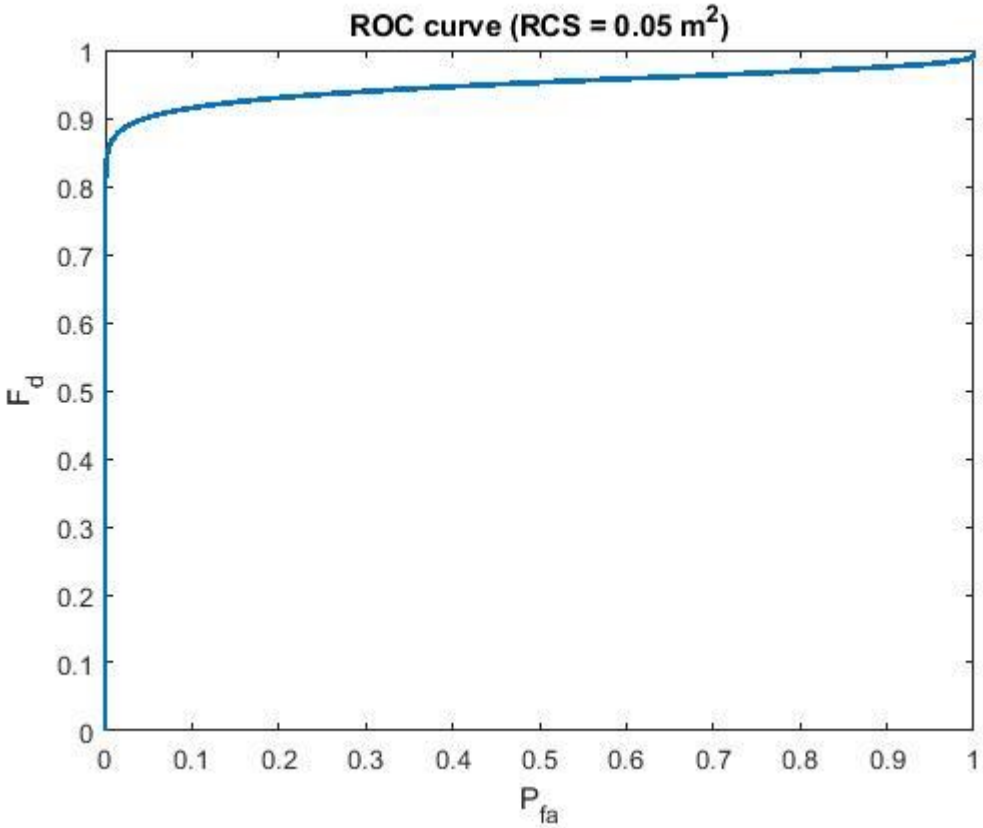


How is the system performance affected if we consider now a target with a RCS of 0.05 square meters?






Threshold vs. detection and false alarm rates
Probability
Threshold level
× 10^-6
P_fa
P_d
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6


ROC curve (RCS = 0.05 m^2)
F_d
P_fa
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Part 1 -A

```
wavelen = 0.3;                                          % Wavelength (m)
pwidth = 5e-07;                                         % Pulse width (s)
sysloss = 2;                                        % System losses (dB)
noisetemp = 290;                                    % Noise temperature (K)
rcs1=0.1;
rcs2 = 1;                                               % Target radar cross
section (m^2)
gain = 30;                                              % Gain (dB)
tgtrng = 25000;                                         % Target range (m)
pkpow = 5000;                                       % Peak transmit power (W)

for i = 500:35000
snr1(i) = radareqsnr(wavelen, i, pkpow, pwidth,'rcs', rcs1, 'gain', ...
    gain, 'loss', sysloss, 'Ts', noisetemp);
end

for i = 500:35000
snr2(i) = radareqsnr(wavelen, i, pkpow, pwidth,'rcs', rcs2, 'gain', ...
    gain, 'loss', sysloss, 'Ts', noisetemp);
end

figure
plot(snr1(500:end))
hold on
plot(snr2(500:end))
hold off
title('SNR Vs Distance');
xlabel('Distance(m)');
ylabel('SNR(dB)');
legend("RCS =0.1m^2","RCS=1m^2");
```

Part 1-B

```
wavelen = 0.3;                                          % Wavelength (m)
pwidth = 5e-07;                                         % Pulse width (s)
sysloss = 2;                                        % System losses (dB)
noisetemp = 290;                                    % Noise temperature (K)
rcs1=0.1;
rcs2 = 1;                                               % Target radar cross
section (m^2)
gain = 30;                                              % Gain (dB)
pkpow = 5000;                                       % Peak transmit power (W)
snr = 16;                                               % SNR (dB)
tgtrng1 = radareqrng(wavelen, snr, pkpow, pwidth,'rcs', rcs1, 'gain', ...
    gain, 'loss', sysloss, 'Ts', noisetemp)
tgtrng2 = radareqrng(wavelen, snr, pkpow, pwidth,'rcs', rcs2, 'gain', ...
    gain, 'loss', sysloss, 'Ts', noisetemp)
```

Part 2

```
clear all,
close all,
clc

waveform = phased.RectangularWaveform('PulseWidth',1e-
6,'PRF',5e3,'OutputFormat','Pulses','NumPulses',1);
antenna = phased.IsotropicAntennaElement('FrequencyRange',[1e9 10e9]);
target = phased.RadarTarget('Model','Swerling1','MeanRCS',0.5,
'PropagationSpeed',physconst('LightSpeed'),'OperatingFrequency',4e9);
antennaplatform = phased.Platform('InitialPosition',[0;0;0],'Velocity',[0;0;0]);
targetplatform = phased.Platform('InitialPosition',[6895.2; 0; 0], 'Velocity',[-
15;-10;0]);
[tgtrng,tgtang] =
rangeangle(targetplatform.InitialPosition,antennaplatform.InitialPosition);

Pd = 0.9;
Pfa = 1e-6;
numpulses = 10;
SNR = albersheim(Pd,Pfa,10);
%target_model="noncoherent";
target_model = 'Swerling1';
maxrange = 1.5e4;
lambda = physconst('LightSpeed')/target.OperatingFrequency;
tau = waveform.PulseWidth;
Ts = 290;
rcs = 0.05;
tgt_range = 6895.2;
Gain = 20;
dbterm = db2pow(SNR - 2*Gain);
Pt = (4*pi)^3*physconst('Boltzmann')*Ts/tau/rcs/lambda^2*maxrange^4*dbterm;

transmitter = phased.Transmitter('PeakPower',10e3,'Gain',20,'LossFactor',0, ...
    'InUseOutputPort',true,'CoherentOnTransmit',true);
radiator = phased.Radiator('Sensor',antenna,...
    'PropagationSpeed',physconst('LightSpeed'),'OperatingFrequency',4e9);
collector = phased.Collector('Sensor',antenna,...
    'PropagationSpeed',physconst('LightSpeed'),'Wavefront','Plane', ...
    'OperatingFrequency',4e9);
receiver = phased.ReceiverPreamp('Gain',20,'NoiseFigure',2, ...
    'ReferenceTemperature',290,'SampleRate',1e6, ...
    'EnableInputPort',true,'SeedSource','Property','Seed',2022);
channel = phased.FreeSpace(...
    'PropagationSpeed',physconst('LightSpeed'), ...
    'OperatingFrequency',4e9,'TwoWayPropagation',false, ...
    'SampleRate',1e6);
ite = 5000;
T = 1/waveform.PRF;
% Get antenna position
txpos = antennaplatform.InitialPosition;
% Allocate array for received echoes
rxsig_H0_collection = zeros(waveform.SampleRate*T, ite);
rxsig_H1_collection = zeros(waveform.SampleRate*T, ite);

for ii = 1:ite
    rxsig_H0 = zeros(waveform.SampleRate*T, numpulses);
    rxsig_H1 = zeros(waveform.SampleRate*T, numpulses);
```

```
    for n = 1:numpulses
     % Update the target position
     [tgtpos,tgtvel] = targetplatform(T);
     % Get the range and angle to the target
     [tgtrng,tgtang] = rangeangle(tgtpos,txpos);
     % Generate the pulse
     sig = waveform();
     % Transmit the pulse. Output transmitter status
     [sig,txstatus] = transmitter(sig);
     % Radiate the pulse toward the target
     sig = radiator(sig,tgtang);
     % Propagate the pulse to the target in free space
     sig = channel(sig,txpos,tgtpos,[0;0;0],tgtvel);
     % Reflect the pulse off the target
         if strcmp(target_model, 'Swerling1')
             sig_H1 = target(sig, true);
         else
             sig_H1 = target(sig);
         end
         % Propagate the echo to the antenna in free space
         sig_H0 = channel(sig, tgtpos, txpos, tgtvel, [0;0;0]);
         sig_H1 = channel(sig_H1,tgtpos, txpos, tgtvel, [0;0;0]);
         % Collect the echo from the incident angle at the antenna
         sig_H0 = collector(sig_H0, tgtang);
         sig_H1 = collector(sig_H1, tgtang);
         % Receive the echo at the antenna when not transmitting
         rxsig_H0(:,n) = receiver(sig_H0, ~txstatus);
         rxsig_H1(:,n) = receiver(sig_H1, ~txstatus);
     end
     rxsig_H0_collection(:, ii) = pulsint(rxsig_H0, 'noncoherent');
     rxsig_H1_collection(:, ii) = pulsint(rxsig_H1, 'noncoherent');
end
t = unigrid(0,1/receiver.SampleRate,T, '[)');
rangegates = physconst('LightSpeed')*t/2;
tgt_bin = find((rangegates - tgt_range) == min(abs(rangegates - tgt_range)));
figure
plot(rangegates/1e3, rxsig_H1_collection(:,1))
hold on
title("Range profile (" + target_model + " model)")
xlabel('range (km)')
ylabel('Power')
xline(tgtrng/1e3, '--r')
axis tight
hold off
%% Part 2b
nbins = 30;
figure
h1 = histogram(rxsig_H1_collection(tgt_bin,:) , nbins, 'Normalization', 'pdf', ...
    'HandleVisibility', 'on');
hold on
h0 = histogram(rxsig_H0_collection(tgt_bin,:) , nbins, 'Normalization', 'pdf', ...
    'HandleVisibility', 'on');
xlabel("Amplitude")
ylabel("Probability")
title("Histograms for H0 and H1")
%% Part 2c
% H0
pd = fitdist(rxsig_H0_collection(tgt_bin, :)', 'normal');
```

```
x_interference = min(rxsig_H0_collection(tgt_bin, :)):(10^(-
9)):max(rxsig_H0_collection(tgt_bin,:));
y_interference = pdf(pd, x_interference);
mu_interference = pd.mu;
sigma_interference = pd.sigma;
% H1
pd = fitdist(rxsig_H1_collection(tgt_bin,:)','normal');
x_target = min(rxsig_H1_collection(tgt_bin, :)):(10^(-
9)):max(rxsig_H1_collection(tgt_bin,:));
y_target = pdf(pd,x_target);
my_target = pd.mu;
sigma_target = pd.sigma;
% PlotPDF
hold on
plot(x_target, y_target, 'b', 'LineWidth',2)
plot(x_interference, y_interference, 'r', 'LineWidth',2)
title("Histograms for H0 and H1 (RC = " + rcs + "m^2)")
legend(["H1" "H0" "Fit Gaussian PDF to H1" "Fit Gaussian PDF to H0"])

%% Part 2d
threshold = (0.2*10^(-7)):(10^(-9)):(16*(10^(-7)));
Pfa = 1 - cdf('normal', threshold, mu_interference, sigma_interference);
Pd = 1 - cdf('normal', threshold, my_target, sigma_target);

figure
plot(threshold, Pfa, threshold, Pd, 'LineWidth', 2)
xlabel("Threshold level")
ylabel("Probability")
title("Threshold vs. detection and false alarm rates")
legend(["P_{fa}" "P_d"])

figure
plot(Pfa,Pd, 'Linewidth',2)
title("ROC curve (RCS = " + rcs + " m^2)")
xlabel("P_{fa}")
ylabel("F_d")
```