BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Course No. **:** EEE 438

Course Title: Wireless Communication Lab. **Section** **:** G1

Experiment No. **:** 03 (Part01)

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Level : 4 **Term:** 2

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Theory

Path loss is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. It is the ratio of the transmit power to the received power. From the free-space propagation equation, path-loss is deterministic and can be given in far-field region (d ≥ $do = 2D2/\lambda$, do >> D, do >> λ, df is the Fraunhofer distance, D is the largest physical dimension of the antenna) as below

$$PL_F(d)[dB] = 10\log\left(\frac{P_t}{P_r}\right) = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right)$$

Here, Pt is the transmit power, Pr is the received power at a distance d, Gt is the transmit antenna gain, Gr is the receive antenna gain and λ is the wavelength of radiation.

Fading is a variation in the amplitude or phase of a wireless signal as it propagates through a communication channel. It can be classified into two different types:

• **Large-scale fading:** It refers to variation in signal strength over large distances, such as the variation in signal strength between a transmitter and a receiver that are far apart. This type of fading is typically caused by the path loss and shadowing effects of large objects such as buildings and hills.

• **Small-scale fading:** It refers to the variation in signal strength over short distances, such as the variation in signal strength between a transmitter and a receiver that are close together. This can happen if the signal is reflected or scattered by objects in the environment.

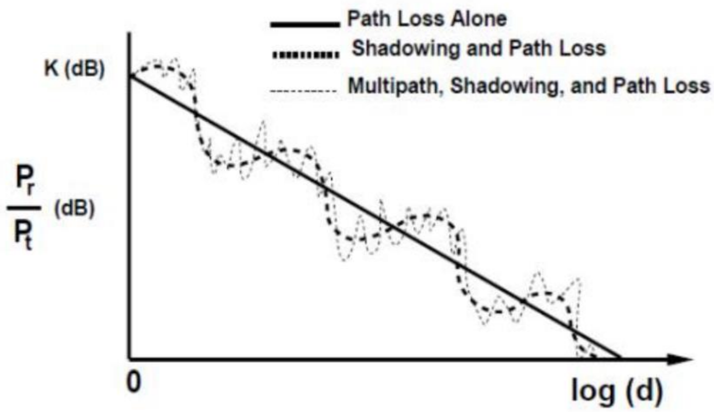


Fig. 1: Path-loss components.

Task 1: Large –Scale Fading

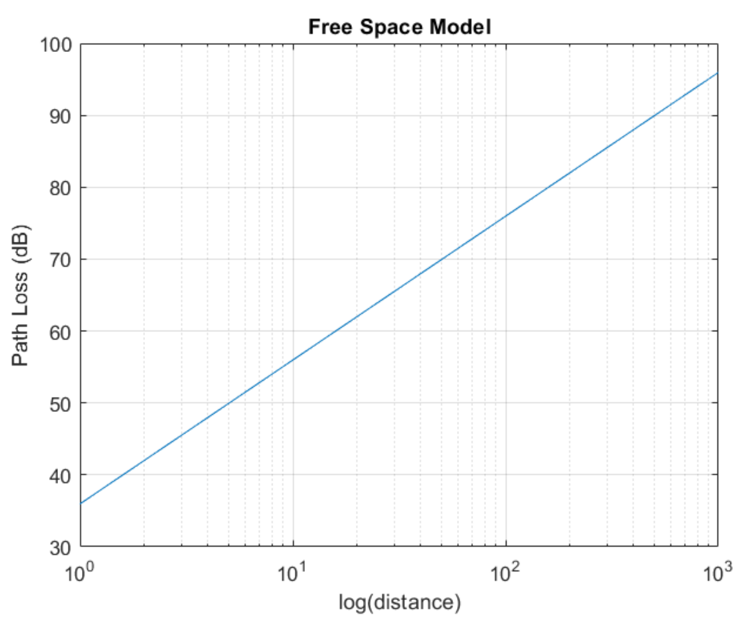
Using MATLAB, simulate and compare the free-space path-loss model, log-distance path-loss model ($n = 2, 3, 6$) and the log-normal shadowing ($n = 2$, $\sigma = 3$ dB) path-loss model. Other common parameters, $f = 1.5$ GHz, $G_t = G_r = 1$, $d_o = 100$m. To compare, plot path-loss in dB over a distance of 1 km.

1. Free Space Model

Code:

```
clc;
clear all;
close all;

c = 3e8;
fc = 1.5e9;
d = 1:1:1000;
Gt=1;
Gr=1;
lam = c/fc;

%% free-space
num = Gt*Gr*(lam^2);
den = (4*pi*d).^2;
PL_fp = 10*log10(num./den);

semilogx(d, PL_fp);
grid on;
xlabel('log(distance)'), ylabel('PL_{free space} (dB)');
```

Plot:

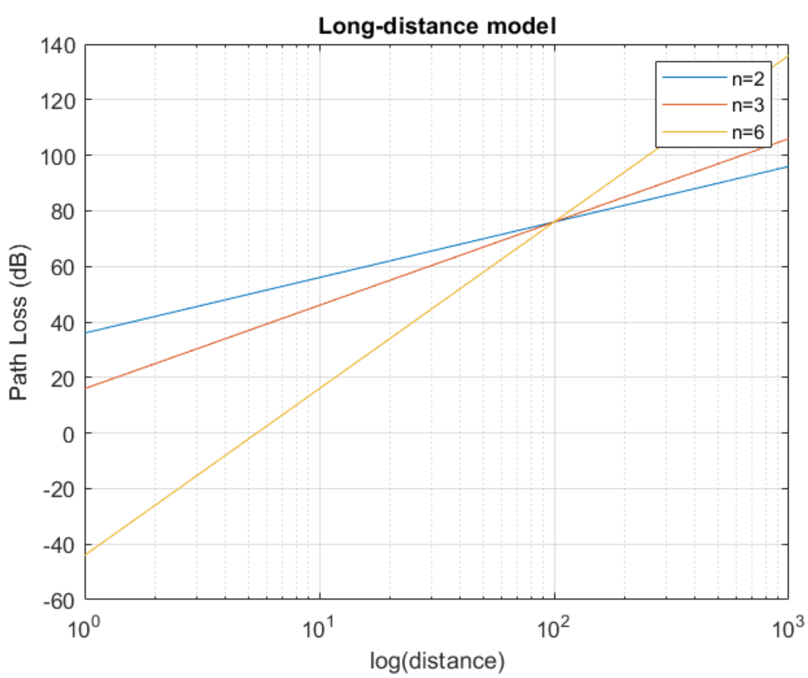


2. Long-distance model

Code:

```
%% long-distance
n = [2, 3, 6];
d0 = 100;

for i = 1:length(n)
    num = Gt*Gr*(lam^2);
    den = (4*pi*d0)^2;
    PL0_ld = -10*log10(num/den);
    PL_ld = PL0_ld + 10*n(i)*log10(d/d0);

    semilogx(d,PL_ld);
    grid on;
    xlabel('log(distance)'), ylabel('Path Loss (dB)');
    title('Long-distance model')
    hold on;
end

legend('n=2', 'n=3', 'n=6');
```

Plot:

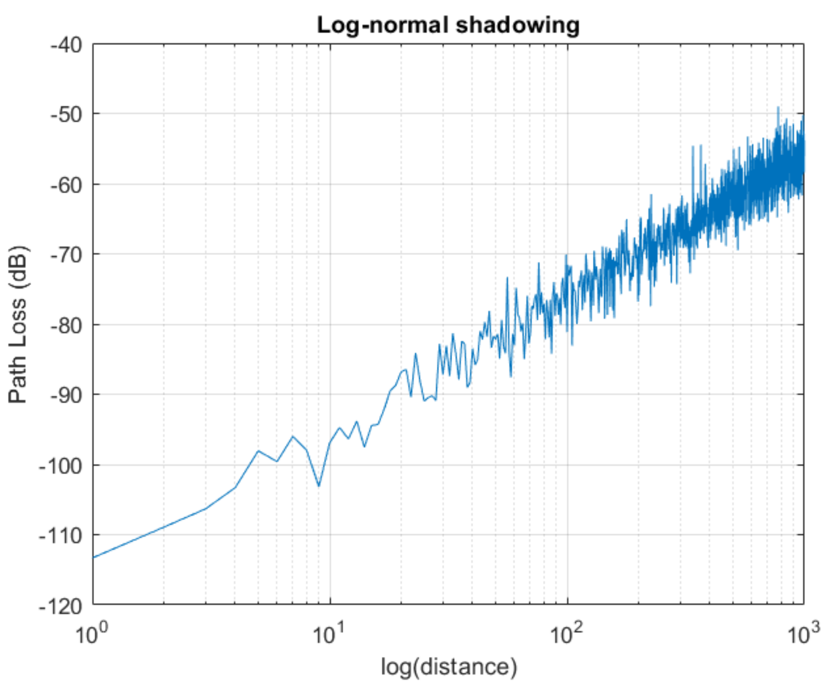


3. Log-normal shadowing

Code:

```
%% log-normal shadowing
num = Gt*Gr*(lam^2);
den = (4*pi*d0)^2;
sigma= 3;
n0=2;
PL0_ln = 10*log10(num./den)+10*n0*log10(d/d0);
PL_ln= PL0_ln + sigma*randn(size(d));
semilogx(d, PL_ln);
grid on;
xlabel('log(distance)'), ylabel('Path Loss (dB)');
title('Log-normal shadowing')
```

Plot:



Analysis:

In Path Loss model, with in increase of n, channel deviates more from Free Space model. We can also notice that for different values of n, path loss is same at reference distance (d0 = 100m). We can also notice from the figure that before d0, lower n values results in lower path loss but after d0 this gets reversed this due to ratio of Log. For Log Normal Shadowing, with increase of n path loss increases with heavy deviations.

Task 2: Small –Scale Fading

(a) Using MATLAB, (i) draw the pdf and cdf of Rayleigh distributed random variables with σ = 1/sqrt(2) and 1. (ii) draw the pdf and cdf of Rician distributed random variables for K = -40dB and 15 dB with σ = 1/sqrt(2). (iii) Is there relation among the results found in (i) and (ii)?

(b) If your transmitted signal is a square pulse of an amplitude = 1 V, draw the received signal amplitude in a Rayleigh (assume σ = 1) and Rician (K = 15 dB, σ = 1) channels for 100 channel realizations. Ignore large-scale fading.

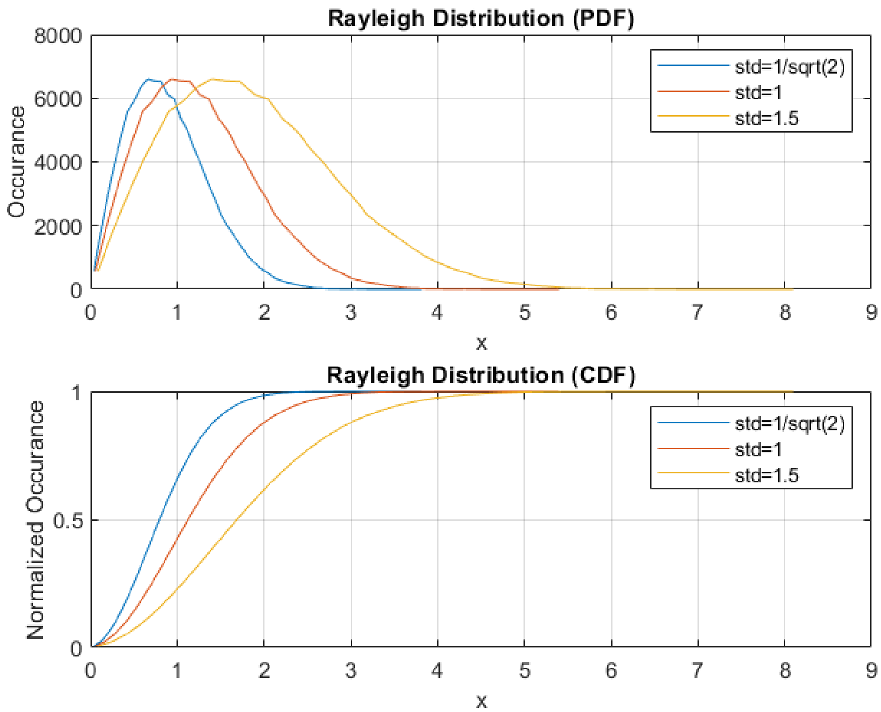
(c) Which of this two channels in part (b) seems better for wireless communications? Explain with justification.

(a)(i) Rayleigh Distribution

Code

```
%% rayleigh
clc;
clear all;
close all;
N = 100000;
level = 50;
sigma = [1/sqrt(2), 1, 1.5];
a= randn(1,N);
b= randn(1,N);
figure(1)

for sd=1:length(sigma)
    rl = sigma(sd)*(sqrt(a.^2+b.^2));
    [PDF, x] = hist(rl, level);
    mx = max(PDF);
    subplot(211)
    plot(x, PDF)
    title('Rayleigh Distribution (PDF)');
    xlabel('x'); ylabel('Occurance')
    grid on; hold on;

    subplot(212)
    plot(x, cumsum(PDF)/max(cumsum(PDF)))
    title('Rayleigh Distribution (CDF)');
    xlabel('x'); ylabel('Normalized Occurance')
    grid on; hold on;

end
subplot(211)
legend('std=1/sqrt(2)', 'std=1', 'std=1.5');
subplot(212)
legend('std=1/sqrt(2)', 'std=1', 'std=1.5');
```

Plot



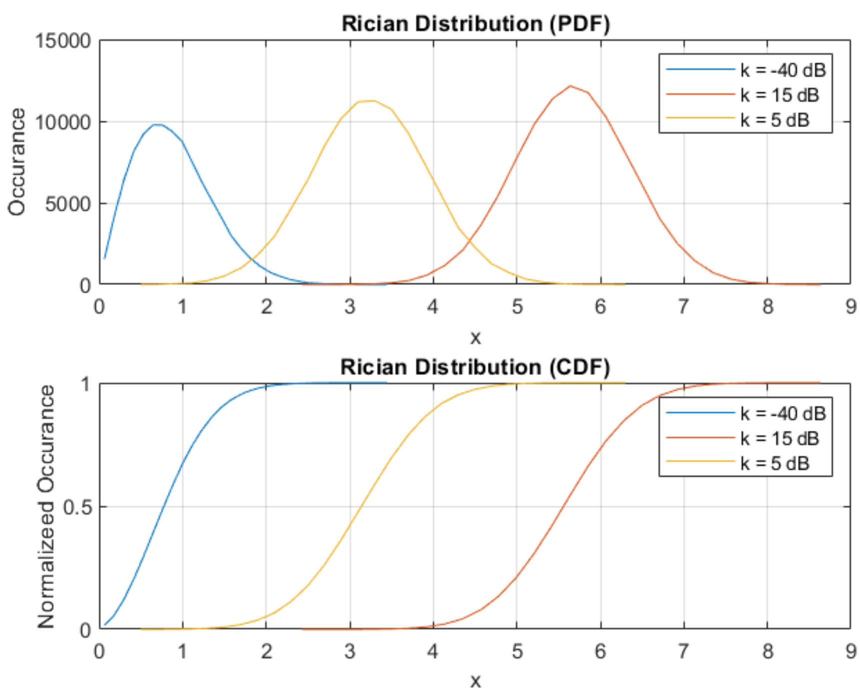
(ii) Rician Distribution

Code

```
%% rician
N = 100000;
level = 30;
sigma = 1/sqrt(2);
K_dB = [-40, 15, 10];
for ki = 1:length(K_dB)
    K = 10^(K_dB(ki)/10);
    s = sqrt(K*2*sigma^2);

    e = s + sigma*randn(1, N);
    f = sigma*randn(1, N);
    rc = sqrt(e.^2+f.^2);
    [PDF, x] = hist(rc, level);
    subplot(211)
    plot(x, PDF);
    title('Rician Distribution (PDF)');
    xlabel('x'); ylabel('Occurance')
    grid on;
    hold on;
```

```
    subplot(212)
    plot(x, cumsum(PDF)/max(cumsum(PDF)))
    title('Rician Distribution (CDF)');
    xlabel('x'); ylabel('Normalizeed Occurance')
    grid on;
    hold on;
end
subplot(211)
legend('k = -40 dB', 'k = 15 dB', 'k = 5 dB');
subplot(212)
legend('k = -40 dB', 'k = 15 dB', 'k = 5 dB');
```

Plot



(iii) Relation between Rayleigh and Rician

Graphically, the PDF of a Rician distribution is a bell-shaped curve, like the Rayleigh distribution but with a non-zero mean, a larger peak and a longer tail. On the other hand, CDF of Rician is a smooth curve that starts from 0, increases at a slower rate than Rayleigh distribution and reaches to 1 at infinity.

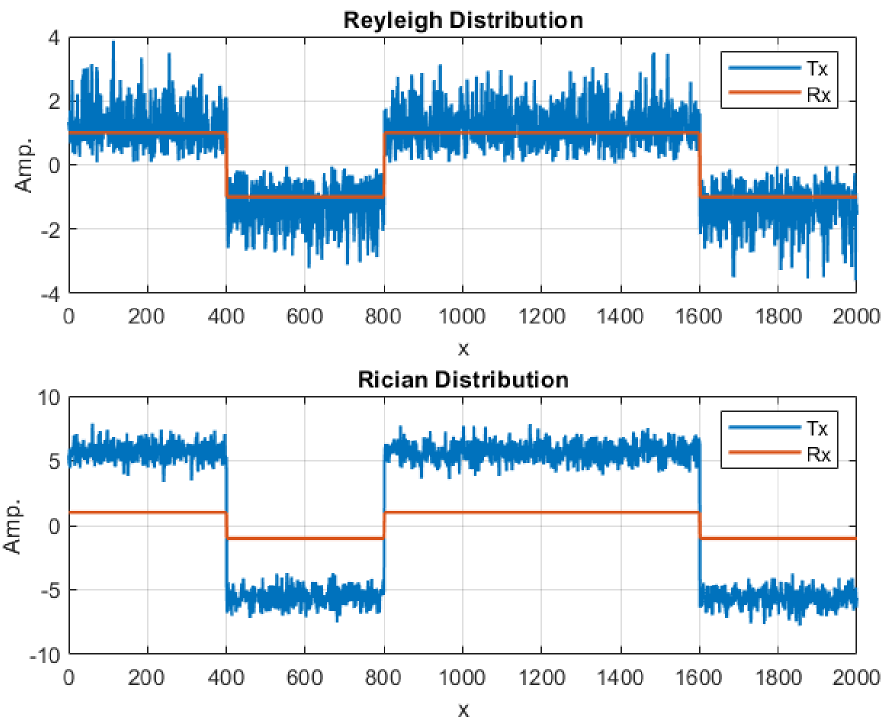
(b) Received Vs Transmitted Signal for Rayleigh and Rician Distribution

Code

```
%% Tx vs Rx Reyleigh
clc;
clear all;
close all;

N = 2000;
sigma = 1;
g=sigma*randn(1, N);
h=sigma*randn(1, N);
rl_sq=sqrt(g.^2+h.^2);
sq_sig = [ones(1, 400), -1*ones(1, 400), ones(1, 400),ones(1, 400),-ones(1,
400)];

rcv_sig = rl_sq.*sq_sig;

subplot(211)
plot(rcv_sig, 'LineWidth',1.3);
hold on; grid on;
plot(sq_sig, 'LineWidth',1.4);
hold off;
title('Reyleigh Distribution');
xlabel('x'); ylabel('Amp.')
legend('Tx', 'Rx');

%% Tx vs Rx Rician

N = 2000;

K_dB = 15;
K = 10^(K_dB/10);
sigma = 1/sqrt(2);

mean1 = sqrt(K*2*sigma^2);

m = mean1 + sigma*randn(1, N);
n = sigma*randn(1, N);
sq_sig = [ones(1, 400), -1*ones(1, 400), ones(1, 400),ones(1, 400),-ones(1,
400)];
rcv_sig = sqrt(m.^2+n.^2).*sq_sig;

subplot(212)
plot(rcv_sig, 'LineWidth',1.3);
hold on; grid on;
plot(sq_sig, 'LineWidth',1.4);
```

```
hold off; grid on;
title('Rician Distribution');
xlabel('x'); ylabel('Amp.')
legend('Tx', 'Rx');
```

Plot



(c) Rayleigh Vs Rician channel comparison

The choices between the Rayleigh and Rician multipath fading channel models would rely on the particulars of the communication system and the environment in which it will function. Both models offer advantages and limitations. The Rayleigh fading model is suitable for simulating wireless channels in an environment with plenty of scatterers, such an urban area. It is very easy to implement. For modeling wireless channels in an environment where line-of-sight (LOS) is predominate, such a suburban region, the Rician fading model is suitable. In comparison to the Rayleigh model, it is harder to implement.