University of Moratuwa
Department of Electronic and Telecommunication Engineering

EN4384 - Wireless and Mobile Communications
Workshop 1

Welcome to Workshop 1 of EN4384. This workshop focuses on fading and shadowing in wireless communication systems.

There are 20 marks available for the successful completion of all tasks in this workshop. This workshop is worth 5% of your overall mark for the module.

You need to prepare a report with your responses to all the tasks and submit it by the deadline indicated on the Moodle page. You may hand-write or use MS Word or LaTeX, as per your convenience. To perform the simulation tasks, you need to use MATLAB.

Abstract: This workshop introduces MATLAB-based modeling of wireless channel impairments, focusing on **small-scale fading**, **large-scale path loss**, and **shadowing**. Students will simulate Rayleigh and Rician fading, log-distance path loss, and log-normal shadowing, and visualize their combined effects on received signal strength. These experiments reinforce the statistical nature of wireless propagation and its impact on link reliability.

Task 1: Large-Scale Path Loss and Shadowing

Concept

Large-scale fading determines the mean received power over large distances due to geometric attenuation and obstacles. It is modeled as:

$$P_r(d) = P_r(d_0) - 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma$$

where:

- n = path-loss exponent (2–5),
- d_0 = reference distance,
- $X_\sigma \sim \mathcal{N}(0, \sigma^2)$ represents shadowing in dB.

MATLAB Simulation

```
% Parameters
d0 = 1;                      % Reference distance [m]
d = logspace(0,3,1000);      % Distance range: 1 to 1000 m
n = 3.2;                     % Path loss exponent
sigma = 6;                   % Shadowing std dev [dB]
Pr0 = -30;                   % Reference received power [dBm]

% Path loss model
```

```
PL_d = Pr0 - 10*n*log10(d/d0);
shadow = sigma*randn(size(d));     % log-normal shadowing (dB)
Pr_d = PL_d + shadow;

% Plot
figure;
semilogx(d, PL_d, 'b', 'LineWidth', 1.5); hold on;
semilogx(d, Pr_d, '.', 'Color', [0.8 0.2 0.2]);
xlabel('Distance (m)'); ylabel('Received Power (dBm)');
legend('Mean Path Loss','With Shadowing');
title('Large-Scale Path Loss and Log-Normal Shadowing');
grid on;
```

Expected Observations

- The mean received power decreases linearly in dB with $\log_{10}(d)$.
- Shadowing introduces local fluctuations around the mean, representing obstacles and reflections.

Task 2: Small-Scale Fading (Rayleigh and Rician Models)

Concept

Small-scale fading arises from multipath interference at the receiver. The received complex baseband signal can be modeled as:

$$r(t) = \sum_{k=1}^{N_p} a_k e^{j\phi_k}$$

When no direct LOS path exists, envelope amplitude follows a **Rayleigh** distribution; with LOS, it follows a **Rician** distribution.

MATLAB Simulation

```
% Parameters
N = 1e5;                   % Number of samples
K = 6;                     % Rician K-factor (ratio of LOS to scattered power)

% Rayleigh fading (no LOS)
h_rayleigh = (randn(N,1) + 1j*randn(N,1))/sqrt(2);

% Rician fading (with LOS)
s = sqrt(K/(K+1));
sigma_r = sqrt(1/(2*(K+1)));
h_rician = s + sigma_r*(randn(N,1)+1j*randn(N,1));

% Envelope
r_rayleigh = abs(h_rayleigh);
r_rician = abs(h_rician);

% Plot histograms
figure;
subplot(2,1,1);
histogram(r_rayleigh,50,'Normalization','pdf');
```

```
hold on;
x = linspace(0,3,200);
pdf_ray = x.*exp(-x.^2/2);
plot(x,pdf_ray,'r','LineWidth',1.5);
title('Rayleigh Fading Amplitude PDF'); xlabel('Amplitude'); ylabel('PDF');

subplot(2,1,2);
histogram(r_rician,50,'Normalization','pdf');
hold on;
pdf_ric = (x./sigma_r^2).*exp(-(x.^2+s^2)/(2*sigma_r^2)).*besseli(0, x*s/(sigma_r^2));
plot(x,pdf_ric,'r','LineWidth',1.5);
title('Rician Fading Amplitude PDF'); xlabel('Amplitude'); ylabel('PDF');
```

Expected Observations

- Rayleigh fading peaks near zero amplitude, indicating deep fades.
- Rician fading reduces fading depth as K increases; a dominant LOS component stabilizes received power.
- The empirical histograms align with theoretical PDFs.

Task 3: Combined Channel Model (Large-Scale + Small-Scale)

Description

To model realistic environments, both fading types are combined. The instantaneous received power is:

$$P_r(d,t) = P_0 \left(\frac{d_0}{d}\right)^n |h(t)|^2 S$$

where S is a log-normal shadowing factor.

MATLAB Simulation

```
% Combine large-scale and small-scale fading
N = 5000; d = logspace(0,3,N);
h = (randn(1,N) + 1j*randn(1,N))/sqrt(2);    % Rayleigh fading
shadow_dB = sigma*randn(1,N);                % Shadowing in dB
shadow = 10.^(shadow_dB/10);                 % Convert to linear
PL = (d0./d).^n;                             % Path loss
Pr_combined = PL .* abs(h).^2 .* shadow;

% Plot results
figure;
semilogx(d,10*log10(Pr_combined),'k.');
xlabel('Distance (m)'); ylabel('Instantaneous Received Power (dB)');
title('Combined Large- and Small-Scale Fading');
grid on;
```

Expected Observations

- The power fluctuates rapidly (small-scale fading) around a mean path-loss curve.
- Shadowing produces slow variations of average power over distance.
- Together, they reproduce the real-world received signal behavior in mobile radio systems.

Task 4: Envelope Statistics and Doppler Effect (Optional)

Doppler Simulation (for Mobile User)

```
fD = 100; Ts = 1e-3; N = 1000;
t = (0:N-1)*Ts;
h_t = (randn(1,N)+1j*randn(1,N))/sqrt(2);
h_dopp = h_t .* exp(1j*2*pi*fD*t);   % Doppler shift
plot(t, 20*log10(abs(h_dopp)));
xlabel('Time (s)'); ylabel('Envelope (dB)');
title('Time-Varying Small-Scale Fading due to Doppler');
```

Observation

As velocity or carrier frequency increases, the Doppler frequency f_D rises, causing faster channel variations (faster fades).

Deliverables

- Plots:
  1. Path loss with and without shadowing.
  2. PDFs of Rayleigh and Rician fading.
  3. Combined power vs. distance plot.
  4. Time-domain fading envelope (Doppler effect).

(10 marks)

- A short report (2–3 pages) interpreting results and identifying key trends.

1. How does the path-loss exponent influence signal coverage range?
2. Why does shadowing follow a log-normal distribution?
3. What is the physical difference between Rayleigh and Rician fading?
4. How does combining shadowing and fading yield realistic power variations?
5. What happens to the received signal envelope as the Doppler frequency increases?

(10 marks)