Hands-On Lab 3: Radio transmission channels

Objectives:

The goal of this lab is to simulate Rayleigh and Rician fading channels and study the effects of the channel on a transmitted signal. You will also calculate coherence bandwidth and Doppler shift for a given wireless communication system.

1. Rician Fading Channel Simulation

We will model a Rician fading channel, characterized by a strong Line of Sight (LOS) component.

```
% Parameters
A = 2; % LOS component amplitude
sigma = 0.5; % Variance of the scattered components
N = 1000; % Number of samples
t = linspace(0, 1, N); % Time vector with N points (same length
as r)

% Rician Fading Channel
r = sqrt((A + sigma*randn(1, N)).^2 + (sigma*randn(1, N)).^2);

% LOS (deterministic signal without fading)
r_LOS = A * ones(1, N); % Pure LOS signal (without fading)

% Plot both signals
figure;
plot(t, r, 'b-', t, r_LOS, 'r--', 'LineWidth', 1.5);
title('Rician Fading Signal vs Pure LOS');
xlabel('Time');
ylabel('Amplitude');
legend('Rician Fading', 'Pure LOS');
grid on;
```

- Simulate a Rician fading channel with different values of the LOS component A. How does increasing A affect the received signal? (A Corresponding to different K factors)
- For a given σ, what is the impact of varying the LOS component on the signal-to-noise ratio (SNR)?

2. Rayleigh Fading Channel Simulation

A Rayleigh channel is a special case of the Rician model when the LOS component is zero (i.e., A=0).

```
% Rayleigh Fading Channel
r_rayleigh = sigma * sqrt(randn(1, N).^2 + randn(1, N).^2);

% Plot the Rayleigh fading signal
figure;
plot(t, r_rayleigh);
title('Rayleigh Fading Signal');
xlabel('Time');
ylabel('Amplitude');
```

- Simulate a Rayleigh fading channel with different values of σ. How does the variance of the scattered components affect the fading depth?

- Compare the power spectral density (PSD) of the Rayleigh fading signal to that of a non-fading signal.

1. Coherence bandwidth, Flat Fading and Frequency-Selective Fading Response

The code you provided generates a wideband signal and simulates the effect of two types of fading channels: flat fading and frequency-selective fading. The fading is modeled in the frequency domain using the coherence bandwidth parameter.

- **Flat Fading Response**: This plot will show the signal after flat fading, with the frequencies beyond the coherence bandwidth (Bc) being attenuated.

- **Frequency-Selective Fading Response**: The signal after frequency-selective fading will show that frequencies outside of Bc are attenuated more strongly.

```
% Parameters
Fs = 10e6; % Sampling frequency (10 MHz)
T = 0.01; % Duration of the signal (10 milliseconds)
t = 0:1/Fs:T-(1/Fs); % Time vector

% Signal Generation with Multiple Frequency Components Centered Around Zero
Bs = 1e6; % Signal bandwidth (1 MHz)
num_frequencies = 10; % Number of frequency components
frequencies = linspace(-Bs/2, Bs/2, num_frequencies); % Spread of frequencies centered
around 0 Hz
signal = sum(cos(2*pi*frequencies.'*t), 1); % Signal with multiple frequency components
centered around 0

% FFT parameters
N = length(signal);
f = (-N/2:N/2-1)*(Fs/N); % Frequency vector for plotting

% Dynamically Set Coherence Bandwidth (Bc) based on Selective Fading Criteria
Bc = 500e3; % Coherence bandwidth set to 500 kHz (half of the signal bandwidth)

% Display Coherence Bandwidth
fprintf('Selected Coherence Bandwidth: %.2f kHz\n', Bc / 1e3);

%% Channel Responses in Frequency Domain

% 1. Flat Fading Channel Response (Coherence Bandwidth > Signal Bandwidth)
H_flat = ones(1, N); % Channel is flat over all frequencies (ideal flat fading)
H_flat(abs(f) > Bc) = 0; % All frequencies above coherence bandwidth are attenuated

% 2. Frequency-Selective Fading Channel Response (Coherence Bandwidth < Signal Bandwidth)
H_selective = exp(-(f/Bc).^2); % Gaussian attenuation of higher frequencies (frequency-
selective)
%% Apply Channel Responses to the Signal
% FFT of the original signal
signal_fft = fftshift(fft(signal));

% Apply flat fading response
signal_flat_fft = signal_fft .* H_flat;

% Apply frequency-selective fading response
signal_selective_fft = signal_fft .* H_selective;

%% Plot Frequency Response of the Channels along with Signal Bandwidth
 % Plot original signal spectrum
figure; subplot(3,1,1);
plot(f/1e6, abs(signal_fft), 'k', 'LineWidth', 1.5); % Frequency in MHz
title('Original Signal Spectrum (Centered Around 0 Hz)');
xlabel('Frequency (MHz)');
ylabel('Magnitude');
grid on;

% Plot the frequency response of flat fading channel
subplot(3,1,2);
plot(f/1e6, abs(signal_flat_fft), 'b', 'LineWidth', 1.5); % Frequency in MHz
hold on;
plot(f/1e6, abs(H_flat), 'r--', 'LineWidth', 1.5); % Channel response
title('Flat Fading: Signal Spectrum and Channel Response');
xlabel('Frequency (MHz)');
ylabel('Magnitude');
legend('Signal after Flat Fading', 'Flat Channel Response');
grid on;

% Plot the frequency response of frequency-selective fading channel
subplot(3,1,3);
plot(f/1e6, abs(signal_selective_fft), 'b', 'LineWidth', 1.5); % Frequency in MHz
hold on;
plot(f/1e6, abs(H_selective), 'r--', 'LineWidth', 1.5); % Channel response
title('Frequency-Selective Fading: Signal Spectrum and Channel Response');
xlabel('Frequency (MHz)');
ylabel('Magnitude');
legend('Signal after Frequency-Selective Fading', 'Selective Channel Response');
grid on;
```

- What is the role of the coherence bandwidth (Bc) in the context of fading channels?
- How does the coherence bandwidth (Bc) compare to the bandwidth of the signal? What effect does this have on the flat fading versus frequency-selective fading channel responses?
- What visual changes do you observe in the signal spectrum when the coherence bandwidth is set to 500 kHz in the frequency-selective fading case?
- Based on your observations, how does the coherence bandwidth affect the overall signal quality in each fading model? Which model is more suitable for high-bandwidth signals, and why?