fs = 8000; f1 = 1000; f2 = 2000; f3 = 3000;

L = 8000\*5; n = (0:L-1);

A = 1/5; % adjust playback volume

x1 = A \* cos(2 \* pi \* n \* f1 / fs);

x2 = A \* cos(2 \* pi \* n \* f2 / fs);

x3 = A \* cos(2 \* pi \* n \* f3 / fs);

noise = (2 \* A \* rand(1, L) - A) \* 0.1; % zero-mean white noise

x = x1 + x2 + x3 + noise;

sound(x, fs);

% Filter orders

N\_values = [21, 51, 151];

% Plot impulse responses and frequency responses for different filter orders

figure;

for i = 1:length(N\_values)

N = N\_values(i);

h = ideal\_lowpass\_impulse\_response(N);

% Plot impulse response

subplot(3, 2, 2 \* i - 1);

stem(0:N-1, h);

title(['Modified Ideal Impulse Response for N = ' num2str(N)]);

xlabel('n');

ylabel('h[n]');

grid on;

% Plot frequency response

subplot(3, 2, 2 \* i);

freq\_range = linspace(0, 1, 1000);

H = freqz(h, 1, freq\_range\*pi);

plot(freq\_range, abs(H));

hold on;

% Plot ideal low-pass filter cutoff at 1/3

ideal\_cutoff\_1\_over\_3 = 0.333;

plot([ideal\_cutoff\_1\_over\_3, ideal\_cutoff\_1\_over\_3], [0, 1], 'b--', 'LineWidth', 1.5, 'DisplayName', 'Ideal Cutoff (pi/3)');

hold off;

title(['Frequency Response for N = ' num2str(N)]);

xlabel('Frequency');

ylabel('|H(f)|');

legend('show');

grid on;

end

% Function to generate the ideal impulse response

function h = ideal\_lowpass\_impulse\_response(N)

n = 0:N-1;

h = sin(pi\*(n - 0.5\*(N-1))/3) ./ (pi\*(n - 0.5\*(N-1)));

h(n == 0.5\*(N-1)) = 1/3; % Handle the singularity at n = 0.5\*(N-1)

end

% Filter orders

N\_values = [21, 51, 151];

% Plot impulse responses and frequency responses for different filter orders

figure;

for i = 1:length(N\_values)

N = N\_values(i);

h = ideal\_lowpass\_impulse\_response(N);

% Plot impulse response

subplot(3, 2, 2 \* i - 1);

stem(0:N-1, h);

title(['Modified Ideal Impulse Response for N = ' num2str(N)]);

xlabel('n');

ylabel('h[n]');

grid on;

% Plot frequency response

subplot(3, 2, 2 \* i);

freq\_range = linspace(0, 1, 1000);

H = freqz(h, 1, freq\_range\*2\*pi);

plot(freq\_range, -1\*abs(H)+1);

hold on;

% Plot ideal low-pass filter cutoff at 1/3

ideal\_cutoff\_1\_over\_3 = 0.333;

plot([ideal\_cutoff\_1\_over\_3, ideal\_cutoff\_1\_over\_3], [0, 1], 'b--', 'LineWidth', 1.5, 'DisplayName', 'Ideal Cutoff (pi/3)');

hold off;

title(['Frequency Response for N = ' num2str(N)]);

xlabel('Frequency');

ylabel('|H(f)|');

legend('show');

grid on;

end

figure

for i = 1:length(N\_values)

% Calculate phase response

N = N\_values(i);

h = ideal\_lowpass\_impulse\_response(N);

f\_rad = linspace(0, pi, N); % Frequency vector in radians

H = ifft(h, N); % Discrete Fourier Transform

phase\_response = angle(H);

% Plot phase response

subplot(3, 1, i);

plot(phase\_response);

title(['Phase Response for N = ' num2str(N)]);

xlabel('Frequency (\omega/\pi)');

ylabel('Phase');

grid on;

% Set x-axis ticks and labels in terms of \omega/\pi

xticks([0, 0.5, 1]);

xticklabels({'0', '\pi/2', '\pi'});

end