**Frequency Modulation System**

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% FM Code

clear all; clc; clf;

% INSTRUCTIONS

# Modulation

% Step 1: Generate a modulating signal

[y, fm] = audioread('TestAudio.wav');

sound(y,fm)

t = linspace(0, length(y)/fm, length(y));

figure;

plot(t, y);

xlabel('Time (s)');

ylabel('Amplitude');

title('Modulating Signal');

% Step 2: Apply Frequency Modulation

Fc = 10e3; % Carrier frequency

% Fs = 2\*Fc;

% Set frequency deviations under test

devf1 = fm/2\*0.5;

devf2 = fm/2\*1;

devf3 = fm/2\*2;

devf4 = fm/2\*5;

devf5 = 75000/2;

% Apply frequency modulation

y\_fmmod1 = fmmod(y,Fc,fm,devf1);

y\_fmmod2 = fmmod(y,Fc,fm,devf2);

y\_fmmod3 = fmmod(y,Fc,fm,devf3);

y\_fmmod4 = fmmod(y,Fc,fm,devf4);

y\_fmmod5 = fmmod(y,Fc,fm,devf5);

figure;

subplot(511)

plot(t, y\_fmmod1); xlabel('Time (s)'); ylabel('Amplitude');

title(['Modulated Signal (\Deltam = ' num2str(devf1) ' Hz)']);

subplot(512)

plot(t, y\_fmmod2); xlabel('Time (s)'); ylabel('Amplitude');

title(['Modulated Signal (\Deltam = ' num2str(devf2) ' Hz)']);

subplot(513)

plot(t, y\_fmmod3); xlabel('Time (s)'); ylabel('Amplitude');

title(['Modulated Signal (\Deltam = ' num2str(devf3) ' Hz)']);

subplot(514)

plot(t, y\_fmmod4); xlabel('Time (s)'); ylabel('Amplitude');

title(['Modulated Signal (\Deltam = ' num2str(devf4) ' Hz)']);

subplot(515)

plot(t, y\_fmmod5); xlabel('Time (s)'); ylabel('Amplitude');

title(['Modulated Signal (\Deltam = ' num2str(devf5) ' Hz)']);

figure;

subplot(511)

fftplotM(y\_fmmod1,fm)

xlim([0 fm/2])

subplot(512)

fftplotM(y\_fmmod2,fm)

xlim([0 fm/2])

subplot(513)

fftplotM(y\_fmmod3,fm)

xlim([0 fm/2])

subplot(514)

fftplotM(y\_fmmod4,fm)

xlim([0 fm/2])

subplot(515)

fftplotM(y\_fmmod5,fm)

xlim([0 fm/2])

% Step 3: Amplify the modulated signals

Gfm = 1;

y\_afmmod1 = Gfm\*y\_fmmod1;

y\_afmmod2 = Gfm\*y\_fmmod2;

y\_afmmod3 = Gfm\*y\_fmmod3;

y\_afmmod4 = Gfm\*y\_fmmod4;

y\_afmmod5 = Gfm\*y\_fmmod5;

# During Transmission

% Step 4: Add noise

% Define SNR values (in dB)

snr1 = 0;

snr2 = 2;

snr3 = 5;

snr4 = 10;

snr5 = -2;

snr6 = -5;

snr7 = -10;

snr8 = 70;

% Apply additive white gaussian noise

% For m = 0.5,

y\_nafmmod11 = awgn(y\_afmmod1,snr1);

y\_nafmmod12 = awgn(y\_afmmod1,snr2);

y\_nafmmod13 = awgn(y\_afmmod1,snr3);

y\_nafmmod14 = awgn(y\_afmmod1,snr4);

y\_nafmmod15 = awgn(y\_afmmod1,snr5);

y\_nafmmod16 = awgn(y\_afmmod1,snr6);

y\_nafmmod17 = awgn(y\_afmmod1,snr7);

y\_nafmmod18 = awgn(y\_afmmod1,snr8);

% For m = 1,

y\_nafmmod21 = awgn(y\_afmmod2,snr1);

y\_nafmmod22 = awgn(y\_afmmod2,snr2);

y\_nafmmod23 = awgn(y\_afmmod2,snr3);

y\_nafmmod24 = awgn(y\_afmmod2,snr4);

y\_nafmmod25 = awgn(y\_afmmod2,snr5);

y\_nafmmod26 = awgn(y\_afmmod2,snr6);

y\_nafmmod27 = awgn(y\_afmmod2,snr7);

y\_nafmmod28 = awgn(y\_afmmod2,snr8);

% For m = 2,

y\_nafmmod31 = awgn(y\_afmmod3,snr1);

y\_nafmmod32 = awgn(y\_afmmod3,snr2);

y\_nafmmod33 = awgn(y\_afmmod3,snr3);

y\_nafmmod34 = awgn(y\_afmmod3,snr4);

y\_nafmmod35 = awgn(y\_afmmod3,snr5);

y\_nafmmod36 = awgn(y\_afmmod3,snr6);

y\_nafmmod37 = awgn(y\_afmmod3,snr7);

y\_nafmmod38 = awgn(y\_afmmod3,snr8);

% For m = 5,

y\_nafmmod41 = awgn(y\_afmmod4,snr1);

y\_nafmmod42 = awgn(y\_afmmod4,snr2);

y\_nafmmod43 = awgn(y\_afmmod4,snr3);

y\_nafmmod44 = awgn(y\_afmmod4,snr4);

y\_nafmmod45 = awgn(y\_afmmod4,snr5);

y\_nafmmod46 = awgn(y\_afmmod4,snr6);

y\_nafmmod47 = awgn(y\_afmmod4,snr7);

y\_nafmmod48 = awgn(y\_afmmod4,snr8);

% For devf = 75 kHz,

y\_nafmmod51 = awgn(y\_afmmod5,snr1);

y\_nafmmod52 = awgn(y\_afmmod5,snr2);

y\_nafmmod53 = awgn(y\_afmmod5,snr3);

y\_nafmmod54 = awgn(y\_afmmod5,snr4);

y\_nafmmod55 = awgn(y\_afmmod5,snr5);

y\_nafmmod56 = awgn(y\_afmmod5,snr6);

y\_nafmmod57 = awgn(y\_afmmod5,snr7);

y\_nafmmod58 = awgn(y\_afmmod5,snr8);

# Demodulation

% Step 5: Demodulate

% For m = 0.5,

y\_fmdemod11 = fmdemod(y\_nafmmod11,Fc,fm,devf1);

y\_fmdemod12 = fmdemod(y\_nafmmod12,Fc,fm,devf1);

y\_fmdemod13 = fmdemod(y\_nafmmod13,Fc,fm,devf1);

y\_fmdemod14 = fmdemod(y\_nafmmod14,Fc,fm,devf1);

y\_fmdemod15 = fmdemod(y\_nafmmod15,Fc,fm,devf1);

y\_fmdemod16 = fmdemod(y\_nafmmod16,Fc,fm,devf1);

y\_fmdemod17 = fmdemod(y\_nafmmod17,Fc,fm,devf1);

y\_fmdemod18 = fmdemod(y\_nafmmod18,Fc,fm,devf1);

% For m = 1,

y\_fmdemod21 = fmdemod(y\_nafmmod21,Fc,fm,devf2);

y\_fmdemod22 = fmdemod(y\_nafmmod22,Fc,fm,devf2);

y\_fmdemod23 = fmdemod(y\_nafmmod23,Fc,fm,devf2);

y\_fmdemod24 = fmdemod(y\_nafmmod24,Fc,fm,devf2);

y\_fmdemod25 = fmdemod(y\_nafmmod25,Fc,fm,devf2);

y\_fmdemod26 = fmdemod(y\_nafmmod26,Fc,fm,devf2);

y\_fmdemod27 = fmdemod(y\_nafmmod27,Fc,fm,devf2);

y\_fmdemod28 = fmdemod(y\_nafmmod28,Fc,fm,devf1);

% For m = 2,

y\_fmdemod31 = fmdemod(y\_nafmmod31,Fc,fm,devf3);

y\_fmdemod32 = fmdemod(y\_nafmmod32,Fc,fm,devf3);

y\_fmdemod33 = fmdemod(y\_nafmmod33,Fc,fm,devf3);

y\_fmdemod34 = fmdemod(y\_nafmmod34,Fc,fm,devf3);

y\_fmdemod35 = fmdemod(y\_nafmmod35,Fc,fm,devf3);

y\_fmdemod36 = fmdemod(y\_nafmmod36,Fc,fm,devf3);

y\_fmdemod37 = fmdemod(y\_nafmmod37,Fc,fm,devf3);

y\_fmdemod38 = fmdemod(y\_nafmmod38,Fc,fm,devf3);

% For m = 5,

y\_fmdemod41 = fmdemod(y\_nafmmod41,Fc,fm,devf4);

y\_fmdemod42 = fmdemod(y\_nafmmod42,Fc,fm,devf4);

y\_fmdemod43 = fmdemod(y\_nafmmod43,Fc,fm,devf4);

y\_fmdemod44 = fmdemod(y\_nafmmod44,Fc,fm,devf4);

y\_fmdemod45 = fmdemod(y\_nafmmod45,Fc,fm,devf4);

y\_fmdemod46 = fmdemod(y\_nafmmod46,Fc,fm,devf4);

y\_fmdemod47 = fmdemod(y\_nafmmod47,Fc,fm,devf4);

y\_fmdemod48 = fmdemod(y\_nafmmod48,Fc,fm,devf4);

% For devf = 75 kHz,

y\_fmdemod51 = fmdemod(y\_nafmmod51,Fc,fm,devf5);

y\_fmdemod52 = fmdemod(y\_nafmmod52,Fc,fm,devf5);

y\_fmdemod53 = fmdemod(y\_nafmmod53,Fc,fm,devf5);

y\_fmdemod54 = fmdemod(y\_nafmmod54,Fc,fm,devf5);

y\_fmdemod55 = fmdemod(y\_nafmmod55,Fc,fm,devf5);

y\_fmdemod56 = fmdemod(y\_nafmmod56,Fc,fm,devf5);

y\_fmdemod57 = fmdemod(y\_nafmmod57,Fc,fm,devf5);

y\_fmdemod58 = fmdemod(y\_nafmmod58,Fc,fm,devf5);

% Design filter

n = 2;

Rs = 20;

Ws = 0.075;

[b,a] = cheby2(n,Rs,Ws);

% Apply filter

% For m = 0.5,

y\_ffmdemod11 = filter(b,a,y\_fmdemod11);

y\_ffmdemod12 = filter(b,a,y\_fmdemod12);

y\_ffmdemod13 = filter(b,a,y\_fmdemod13);

y\_ffmdemod14 = filter(b,a,y\_fmdemod14);

y\_ffmdemod15 = filter(b,a,y\_fmdemod15);

y\_ffmdemod16 = filter(b,a,y\_fmdemod16);

y\_ffmdemod17 = filter(b,a,y\_fmdemod17);

y\_ffmdemod18 = filter(b,a,y\_fmdemod18);

% For m = 1,

y\_ffmdemod21 = filter(b,a,y\_fmdemod21);

y\_ffmdemod22 = filter(b,a,y\_fmdemod22);

y\_ffmdemod23 = filter(b,a,y\_fmdemod23);

y\_ffmdemod24 = filter(b,a,y\_fmdemod24);

y\_ffmdemod25 = filter(b,a,y\_fmdemod25);

y\_ffmdemod26 = filter(b,a,y\_fmdemod26);

y\_ffmdemod27 = filter(b,a,y\_fmdemod27);

y\_ffmdemod28 = filter(b,a,y\_fmdemod28);

% For m = 2,

y\_ffmdemod31 = filter(b,a,y\_fmdemod31);

y\_ffmdemod32 = filter(b,a,y\_fmdemod32);

y\_ffmdemod33 = filter(b,a,y\_fmdemod33);

y\_ffmdemod34 = filter(b,a,y\_fmdemod34);

y\_ffmdemod35 = filter(b,a,y\_fmdemod35);

y\_ffmdemod36 = filter(b,a,y\_fmdemod36);

y\_ffmdemod37 = filter(b,a,y\_fmdemod37);

y\_ffmdemod38 = filter(b,a,y\_fmdemod38);

% For m = 5,

y\_ffmdemod41 = filter(b,a,y\_fmdemod41);

y\_ffmdemod42 = filter(b,a,y\_fmdemod42);

y\_ffmdemod43 = filter(b,a,y\_fmdemod43);

y\_ffmdemod44 = filter(b,a,y\_fmdemod44);

y\_ffmdemod45 = filter(b,a,y\_fmdemod45);

y\_ffmdemod46 = filter(b,a,y\_fmdemod46);

y\_ffmdemod47 = filter(b,a,y\_fmdemod47);

y\_ffmdemod48 = filter(b,a,y\_fmdemod48);

% For devf = 75 kHz,

y\_ffmdemod51 = filter(b,a,y\_fmdemod51);

y\_ffmdemod52 = filter(b,a,y\_fmdemod52);

y\_ffmdemod53 = filter(b,a,y\_fmdemod53);

y\_ffmdemod54 = filter(b,a,y\_fmdemod54);

y\_ffmdemod55 = filter(b,a,y\_fmdemod55);

y\_ffmdemod56 = filter(b,a,y\_fmdemod56);

y\_ffmdemod57 = filter(b,a,y\_fmdemod57);

y\_ffmdemod58 = filter(b,a,y\_fmdemod58);

# **RECOVERY**

% Recover the received signals.

% Comparison Graph 1: Using SNR = 0 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod11, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod21, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod31, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod41, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod51, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = 0 dB with Different Modulation Index");

% Comparison Graph 2: Using SNR = 2 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod12, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod22, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod32, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod42, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod52, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = 2 dB with Different Modulation Index");

% Comparison Graph 3: Using SNR = 5 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod13, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod23, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod33, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod43, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod53, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = 5 dB with Different Modulation Index");

% Comparison Graph 4: Using SNR = 10 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod14, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod24, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod34, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod44, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod54, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = 10 dB with Different Modulation Index");

% Comparison Graph 5: Using SNR = -2 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod15, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod25, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod35, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod45, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod55, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = -2 dB with Different Modulation Index");

% Comparison Graph 6: Using SNR = -5 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod16, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod26, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod36, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod46, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod56, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = -5 dB with Different Modulation Index");

% Comparison Graph 7: Using SNR = -10 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod17, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod27, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod37, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod47, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod57, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = -10 dB with Different Modulation Index");

% Comparison Graph 8: Using SNR = 70 dB with different modulation indices

figure;

subplot(511); plot(t,y\_fmdemod18, t, y); grid on; xlim([0 3.4]); title("m = 0.5");

subplot(512); plot(t,y\_fmdemod28, t, y); grid on; xlim([0 3.4]); title("m = 1");

subplot(513); plot(t,y\_fmdemod38, t, y); grid on; xlim([0 3.4]); title("m = 2");

subplot(514); plot(t,y\_fmdemod48, t, y); grid on; xlim([0 3.4]); title("m = 5");

subplot(515); plot(t,y\_fmdemod58, t, y); grid on; xlim([0 3.4]); title("m = 1.5625");

sgtitle("Comparison of Signals for SNR = 70 dB with Different Modulation Index");

% FFT Plots 1: Using SNR = 0 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod11, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod21, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod31, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod41, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod51, fm); title("m = 1.5625");

% FFT Plots 2: Using SNR = 2 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod12, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod22, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod32, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod42, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod52, fm); title("m = 1.5625");

% FFT Plots 3: Using SNR = 5 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod13, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod23, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod33, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod43, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod53, fm); title("m = 1.5625");

% FFT Plots 4: Using SNR = 10 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod14, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod24, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod34, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod44, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod54, fm); title("m = 1.5625");

% FFT Plots 5: Using SNR = -2 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod15, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod25, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod35, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod45, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod55, fm); title("m = 1.5625");

% FFT Plots 6: Using SNR = -5 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod16, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod26, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod36, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod46, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod56, fm); title("m = 1.5625");

% FFT Plots 7: Using SNR = -10 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod17, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod27, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod37, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod47, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod57, fm); title("m = 1.5625");

% FFT Plots 8: Using SNR = 70 dB with different modulation indices

figure;

subplot(511); fftplotD(y\_fmdemod18, fm); title("m = 0.5");

subplot(512); fftplotD(y\_fmdemod28, fm); title("m = 1");

subplot(513); fftplotD(y\_fmdemod38, fm); title("m = 2");

subplot(514); fftplotD(y\_fmdemod48, fm); title("m = 5");

subplot(515); fftplotD(y\_fmdemod58, fm); title("m = 1.5625");

function fftplotM(signal,Fs)

[N,~] = size(signal);

t = -Fs/2:Fs/(N-1):Fs/2;

signalfreq = pow2db(abs(fft(signal)));

plot(t,signalfreq); xlabel("Frequency (Hz)"); ylabel("Amplitude"); xlim([0 fm/2])

sgtitle("Frequency Response of Modulated Signal")

end

function fftplotD(signal,Fs)

[N,~] = size(signal);

t = -Fs/2:Fs/(N-1):Fs/2;

signalfreq = pow2db(abs(fft(signal)));

plot(t,signalfreq); xlabel("Frequency (Hz)"); ylabel("Amplitude");

sgtitle("Frequency Response of Demodulated Signals")

end