Communcations and Networking Lab 5

Multiple Access Protocols

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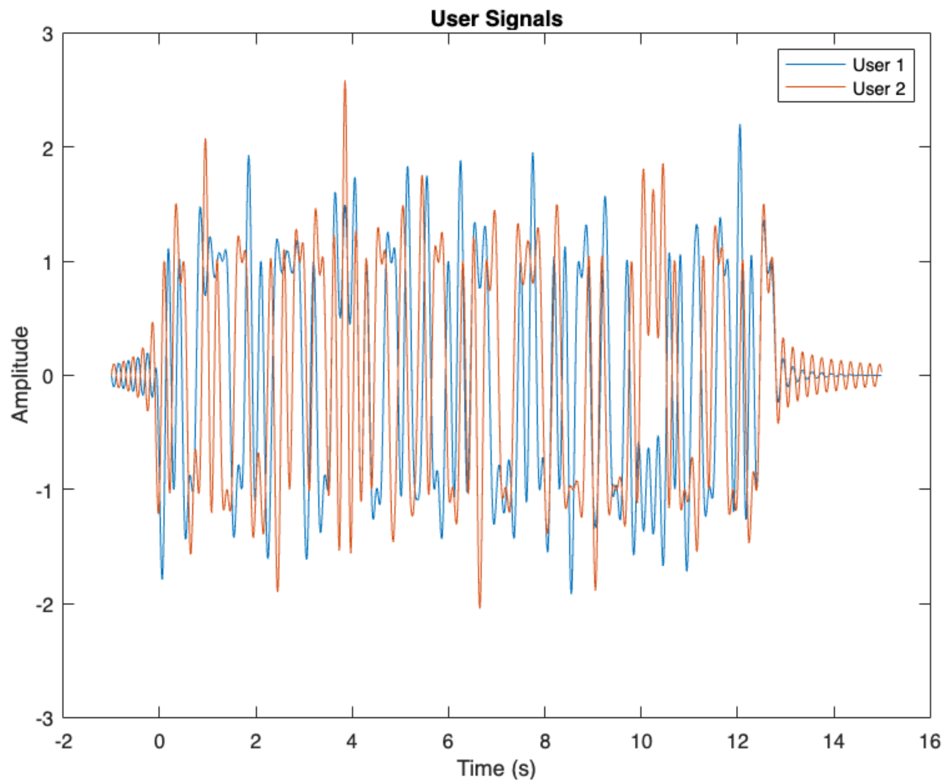
Part 1: Data Generation

```
Fs = 100;
T = 1/Fs;
t = -1:T:14.99;

user1 = zeros(1, length(t));
user2 = zeros(1, length(t));

% generating random sequences for each user
rand1 = 2 * round(rand(1, 128)) - 1;
rand2 = 2 * round(rand(1, 128)) - 1;
```

Look up the rand() function - what transformation did we apply, and what is the result?

- The `rand` function generates random numbers between 0 and 1. By multiplying by 2 and rounding, we transform the range to [0, 2] and then to [-1, 1].

```
for i = 1:128
    user1 = user1 + rand1(i) * sinc((t - (i-1) * 0.1) / 0.1);
    user2 = user2 + rand2(i) * sinc((t - (i-1) * 0.1) / 0.1);
end

% plotting the signals
figure;
plot(t, user1, t, user2);
title('User Signals');
xlabel('Time (s)');
ylabel('Amplitude');
legend('User 1', 'User 2');
```

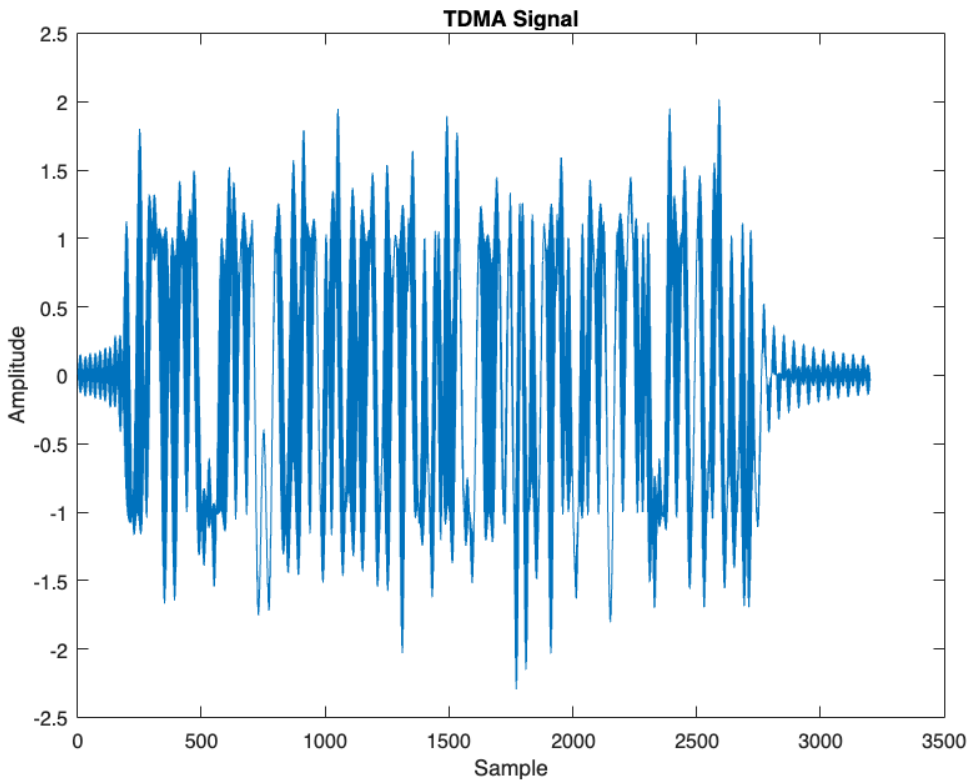


Are the signals visibly different?

- Yes, they are clearly different in the plot.

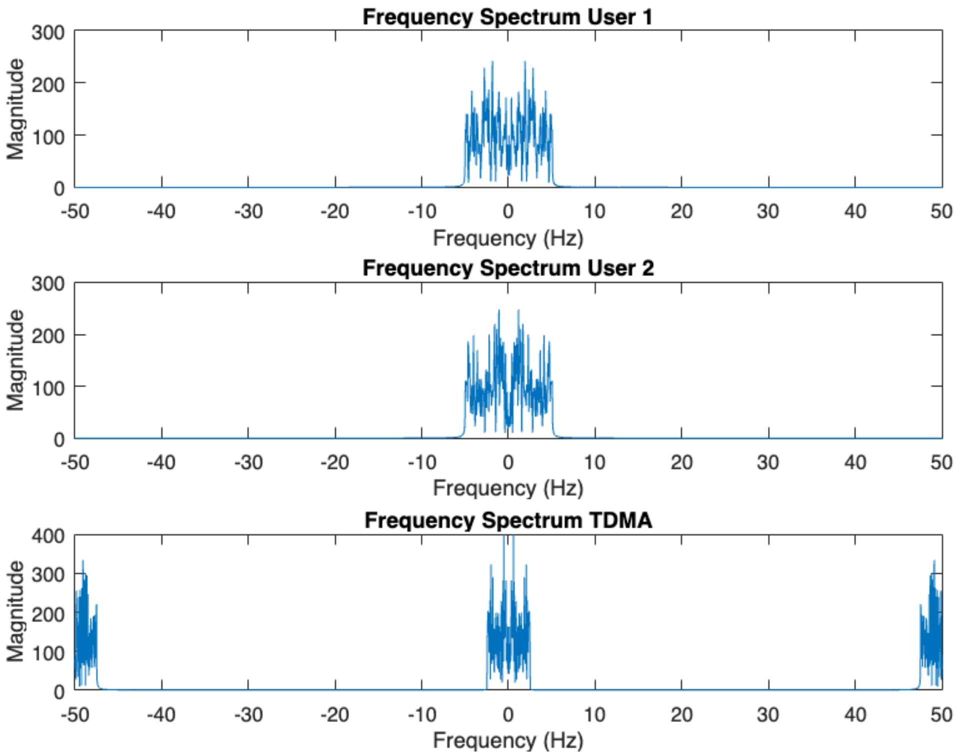
Part 2: TDMA

```
time_div = 0.0100; % time division in seconds
sample_div = round(time_div * Fs); % time division in samples

xTDMA = [];
for i = 1:sample_div:length(user1)
    xTDMA = [xTDMA, user1(i:min(i+sample_div-1, length(user1))),
user2(i:min(i+sample_div-1, length(user2)))];
end

% plotting the TDMA signal
figure;
plot(xTDMA);
title('TDMA Signal');
xlabel('Sample');
ylabel('Amplitude');
```




```
% fft
X_user1 = fft(user1);
shift_user1 = fftshift(X_user1);
X_user2 = fft(user2);
shift_user2 = fftshift(X_user2);
X_TDMA = fft(xTDMA);
shift_TDMA = fftshift(X_TDMA);

freqaxis_user = Fs * linspace(-0.5, 0.5, length(t));
freqaxis_TDMA = Fs * linspace(-0.5, 0.5, length(xTDMA));

figure;
subplot(3,1,1)
plot(freqaxis_user, abs(shift_user1));
title('Frequency Spectrum User 1');
xlabel('Frequency (Hz)');
ylabel('Magnitude');

subplot(3,1,2)
plot(freqaxis_user, abs(shift_user2));
title('Frequency Spectrum User 2');
xlabel('Frequency (Hz)');
ylabel('Magnitude');

subplot(3,1,3)
```

```
plot(freqaxis_TDMA, abs(shift_TDMA));
title('Frequency Spectrum TDMA');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
```

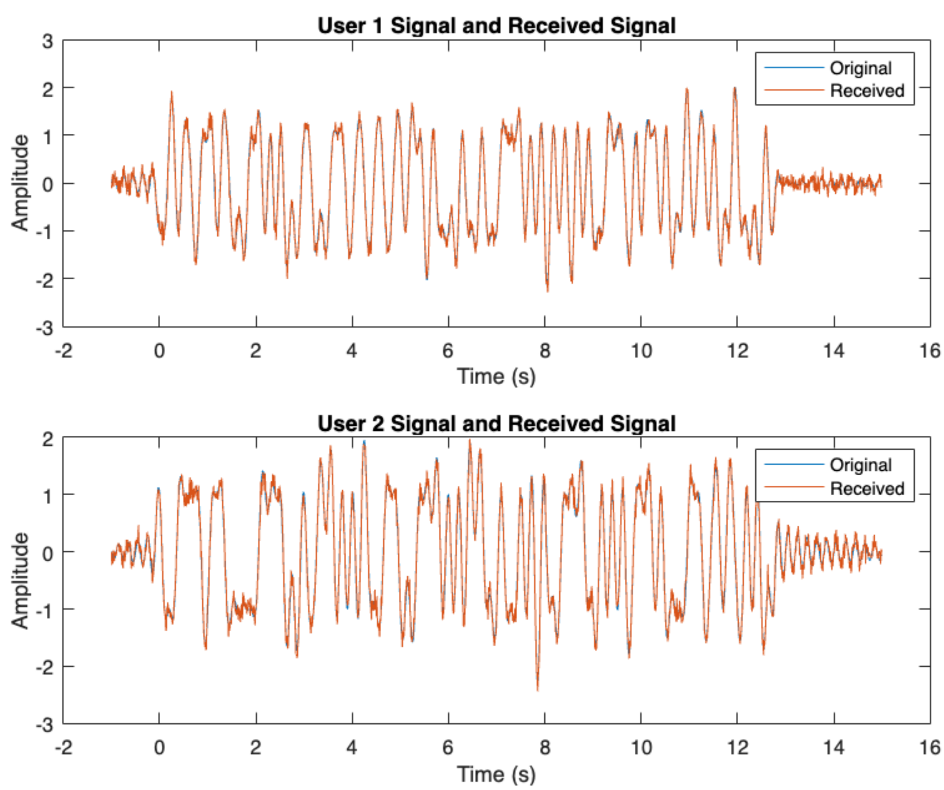


What conclusions can you draw from these plots?

- User1 and user2 have mostly distinct frequency components because they are radnomly generated signals.
- The TDMA signal's frequency spectrum shows combined frequency components from both user1 and user2. This shows that theTDMA signal contains frequency information from both users

```
% tdma demodulation

rx_TDMA = xTDMA + 0.1 * randn(size(xTDMA));

rx_user1 = zeros(1, length(t));
rx_user2 = zeros(1, length(t));

% length of each user signal in the signal
N = length(user1);

for i = 1:sample_div:N
    % determine the end index for the current chunk
    end_idx = min(i + sample_div - 1, N);
```

```
    % extract the received signal for user1
    rx_user1(i:end_idx) = rx_TDMA(2*(i-1)+1:2:(2*end_idx-1));

    % extract the received signal for user2
    rx_user2(i:end_idx) = rx_TDMA(2*(i-1)+2:2:(2*end_idx));
end

% Plotting the received signals
figure;
subplot(2,1,1);
plot(t, user1, t, rx_user1);
title('User 1 Signal and Received Signal');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original', 'Received');

subplot(2,1,2);
plot(t, user2, t, rx_user2);
title('User 2 Signal and Received Signal');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original', 'Received');
```

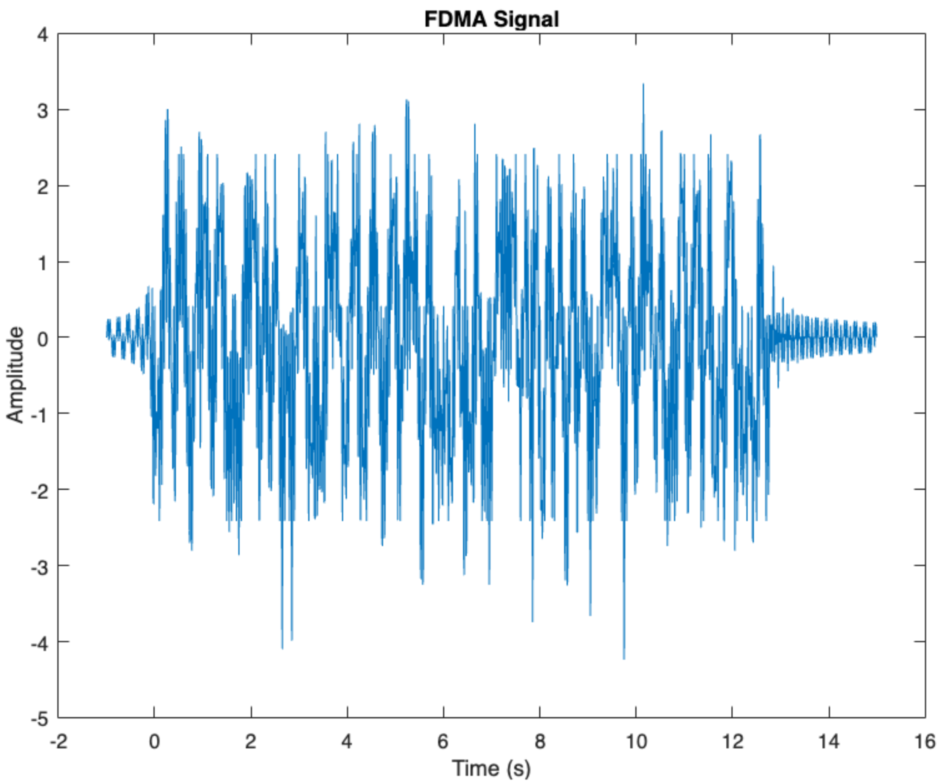


Can you tell that the received signal is the same?

- Yes, they overlap very closely.

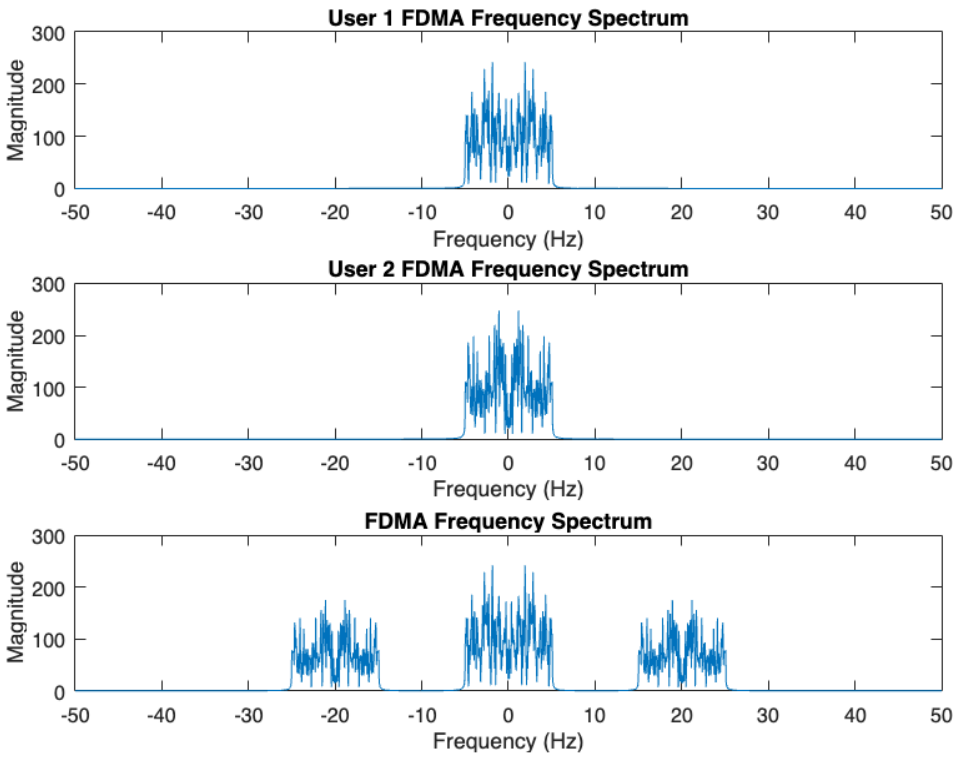
Part 3: FDMA

```
freq_spacing = 20; % frequency spacing in Hz
modulator = cos(2 * pi * freq_spacing * t);

xFDMA = user1 + sqrt(2) * user2 .* modulator;

% plotting the FDMA signal
figure;
plot(t, xFDMA);
title('FDMA Signal');
xlabel('Time (s)');
ylabel('Amplitude');
```

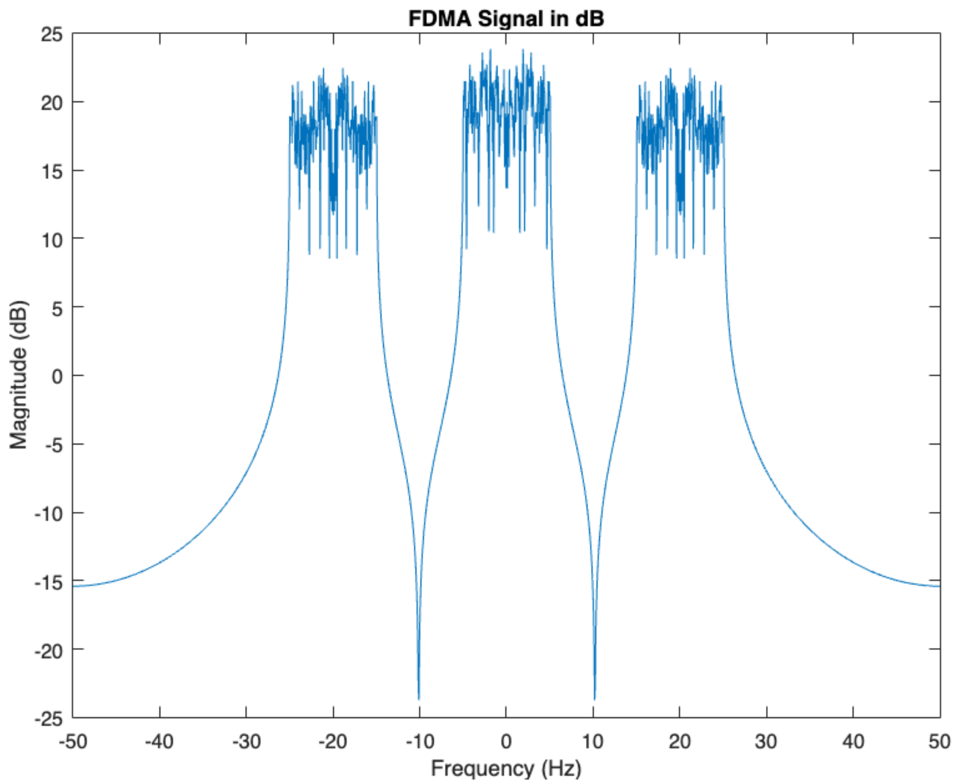



```
% analysis of fdma
X_FDMA = fft(xFDMA);
shift_FDMA = fftshift(X_FDMA);

figure;
subplot(3,1,1)
plot(freqaxis_user, abs(shift_user1));
title('User 1 FDMA Frequency Spectrum');
```

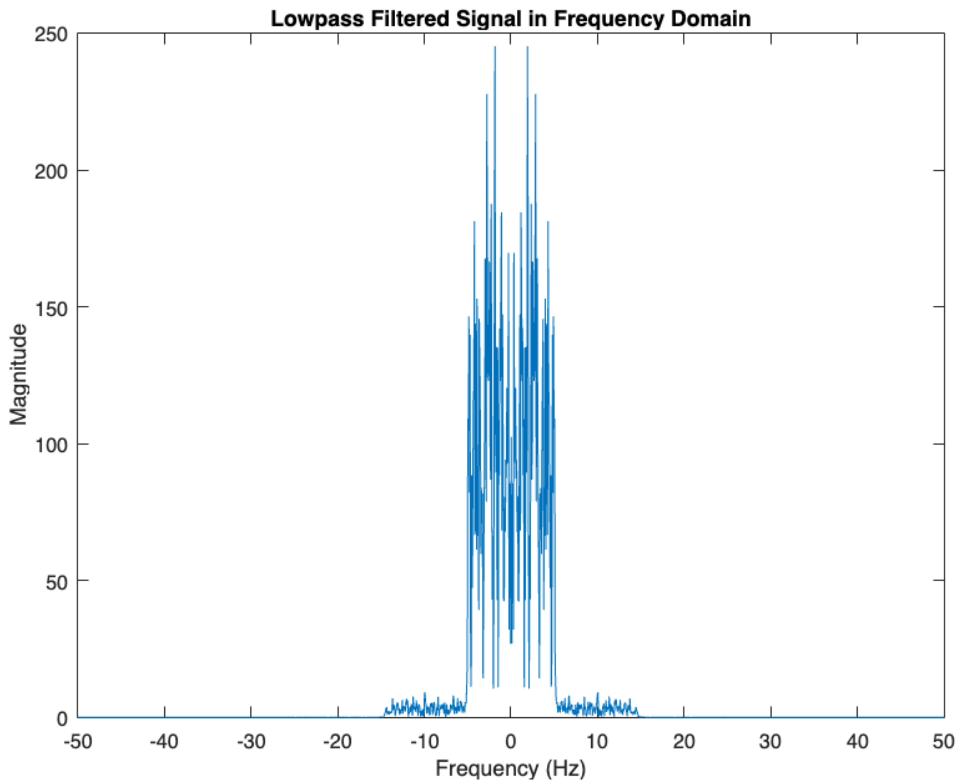
```
xlabel('Frequency (Hz)');
ylabel('Magnitude');

subplot(3,1,2)
plot(freqaxis_user, abs(shift_user2));
title('User 2 FDMA Frequency Spectrum');
xlabel('Frequency (Hz)');
ylabel('Magnitude');

subplot(3,1,3)
plot(freqaxis_user, abs(shift_FDMA));
title('FDMA Frequency Spectrum');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
```




```
% Plotting in dB
figure;
plot(freqaxis_user, 10*log10(abs(shift_FDMA)));
title('FDMA Signal in dB');
xlabel('Frequency (Hz)');
ylabel('Magnitude (dB)');
```



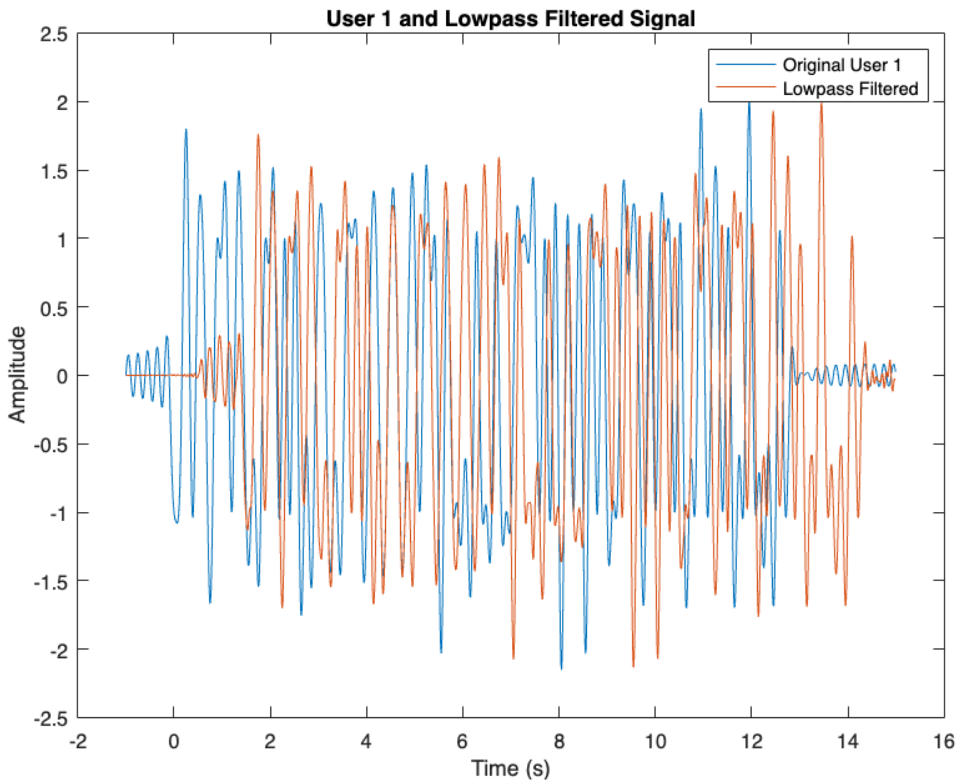

```
% adding a filter

load('fdma_lowpass.mat');

received = xFDMA + 0.1 * randn(size(xFDMA));

% filtering the signal
lowpassed = filter(fdma_lowpass, 1, received);

% plotting the filtered signal in frequency
figure;
plot(freqaxis_user, abs(fftshift(fft(lowpassed))));
title('Lowpass Filtered Signal in Frequency Domain');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
```



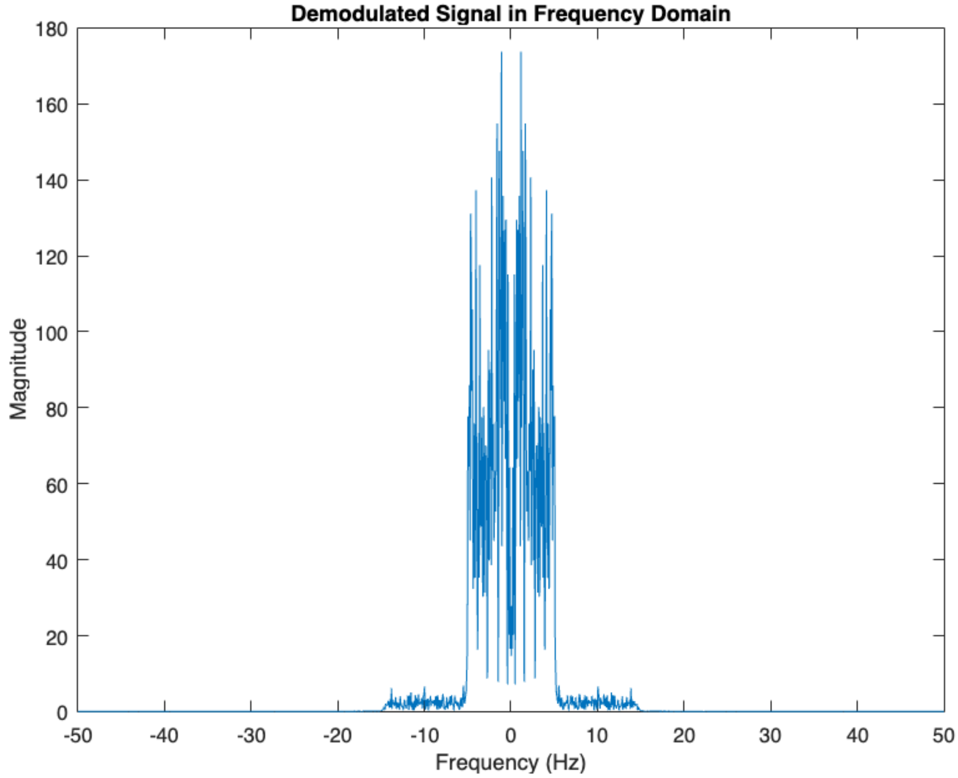
Does it look like you wanted your low pass filtered signal to look?

- Yes, the higher frequqnecies are now attenuated

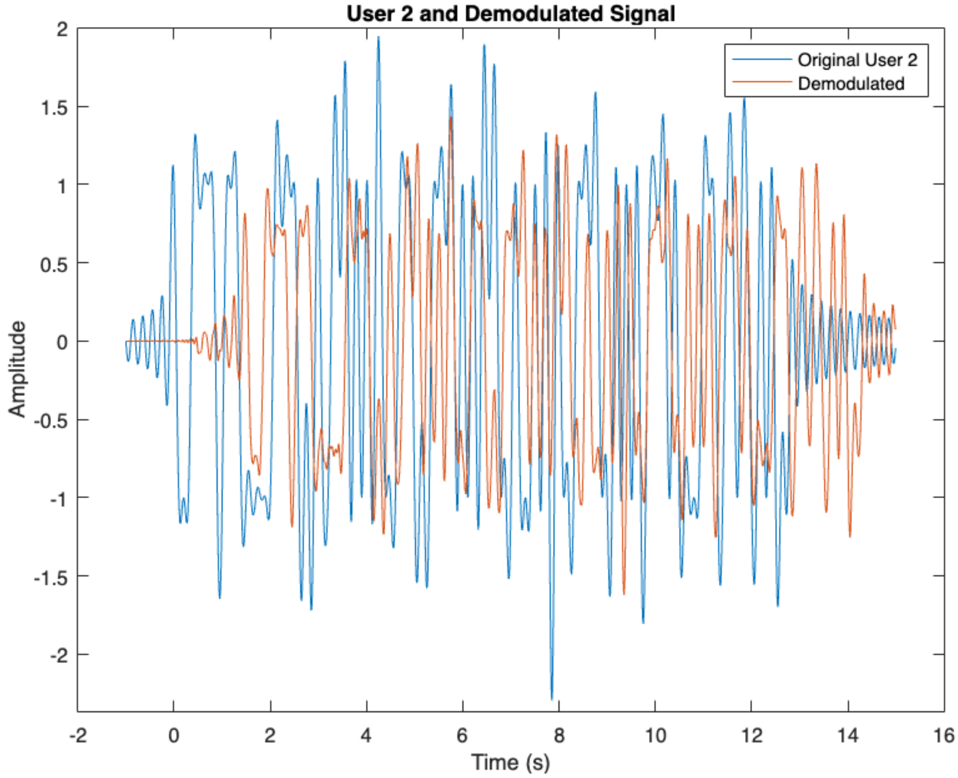
```
% plotting the filtered signal in time
figure;
plot(t, user1, t, lowpassed);
title('User 1 and Lowpass Filtered Signal');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original User 1', 'Lowpass Filtered');
```




```
% demodulation
demodulator = cos(2 * pi * freq_spacing * t);
demodulated = received .* demodulator;

% Applying lowpass filter
lowpassed_demodulated = filter(fdma_lowpass, 1, demodulated);

% Plotting the demodulated signal in frequency
figure;
plot(freqaxis_user, abs(fftshift(fft(lowpassed_demodulated))));
title('Demodulated Signal in Frequency Domain');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
```




```
% Plotting the demodulated signal in time
figure;
plot(t, user2, t, lowpassed_demodulated);
title('User 2 and Demodulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original User 2', 'Demodulated');
```



Answers to Questions

What did you observe from the experiments?

- The TDMA effectively interleaves the signals in the time domain, while FDMA separates the signals in the frequency domain. The recovered signals after demodulation have some noise but resemble the original signals.

If you could expand this experiment how would you do it?

- We would expand the experiment to include more users and explore the impact of different modulation techniques and noise levels on signal demodulation.

How does the experiment relate to the course topic?

- The experiment relates to multiple access methods by demonstrating implementations of TDMA and FDMA

What did you learn from the experiment?

- We learned how to implement and analyze TDMA and FDMA and the practical challenges of signal recovery in with noise