Digital Signal Processing Lab

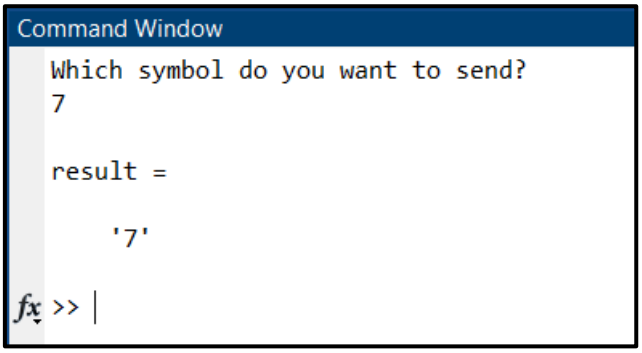
Experiment 3

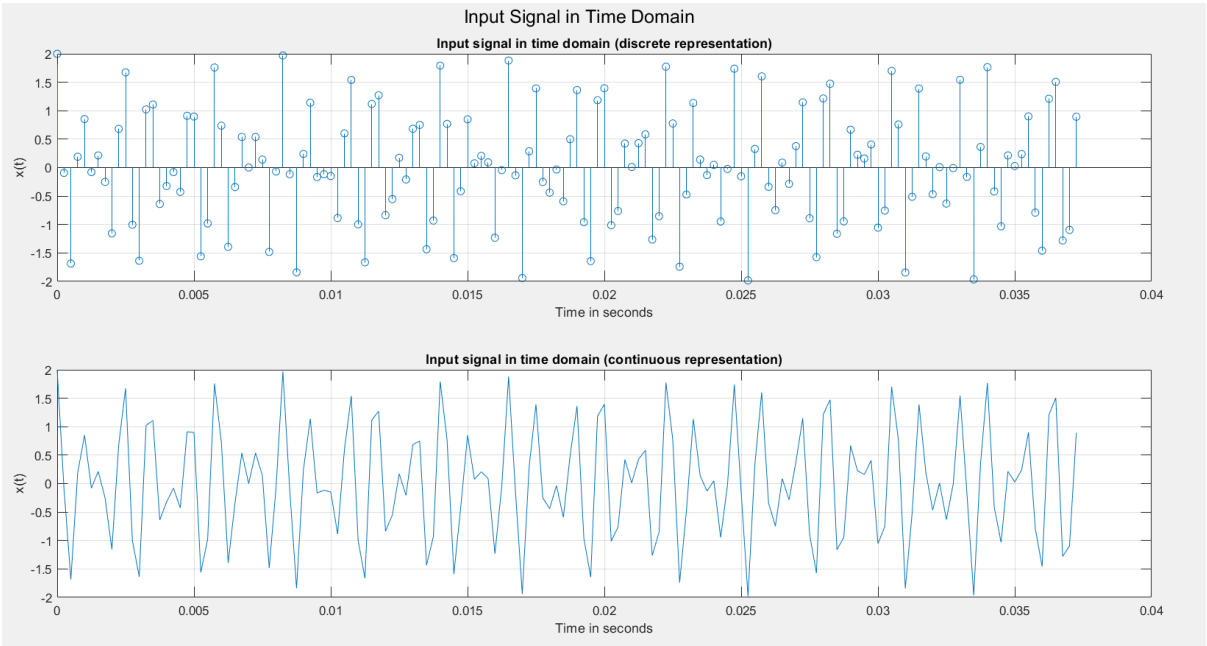
By Hardik Tibrewal (18EC10020)

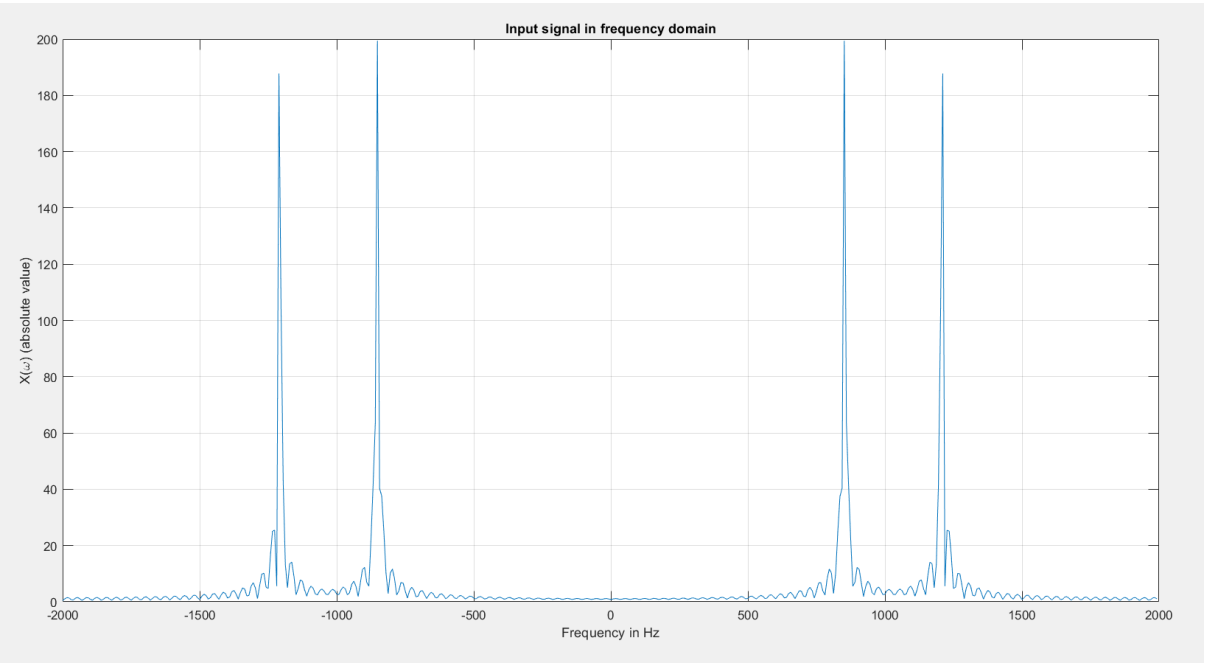
Aim:

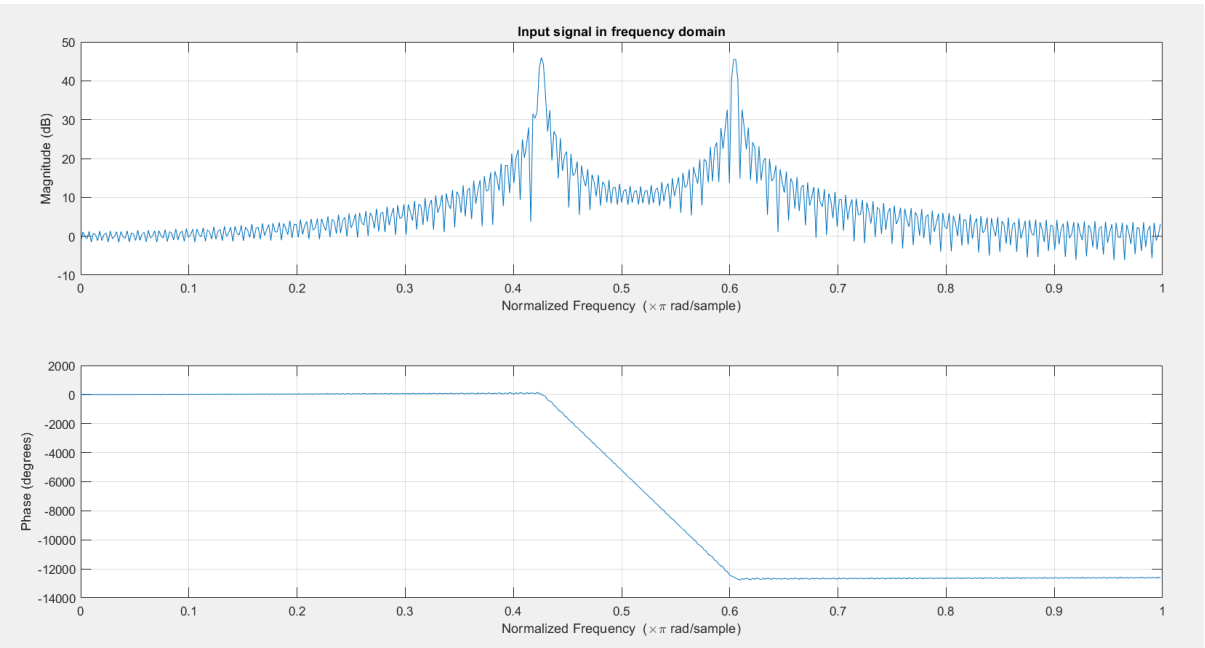
To study and analyse a Dual Tone Multi-Frequency (DTMF) coder and decoder using Digital FIR Filters in MATLAB

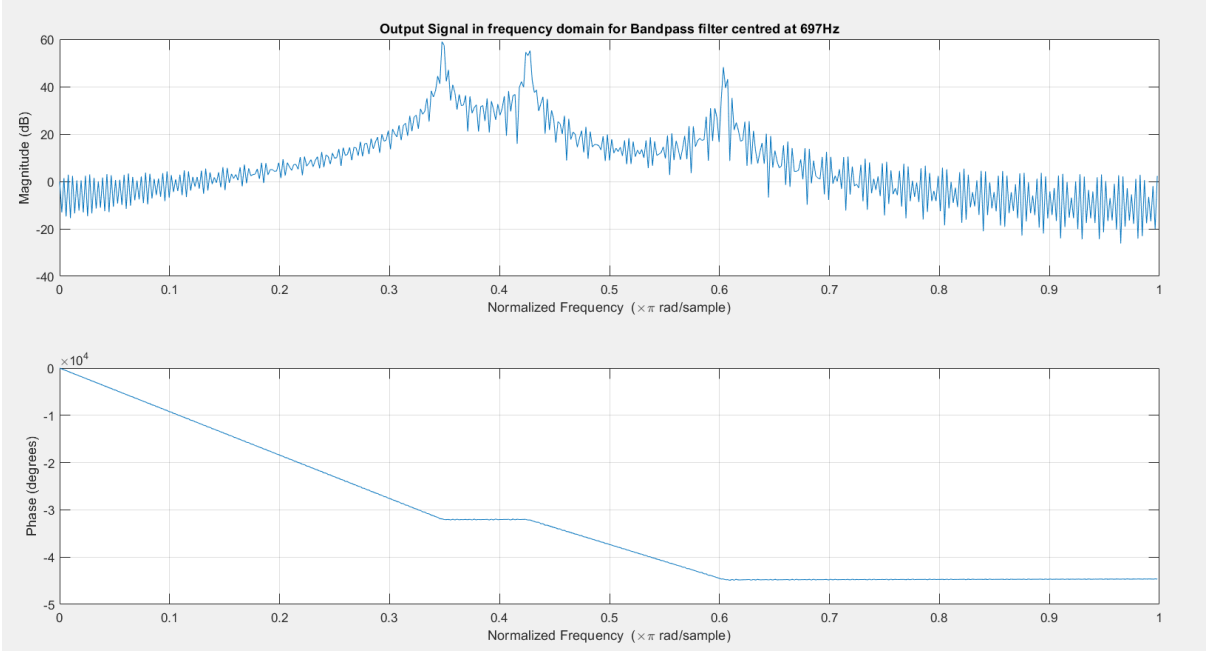
Plots:

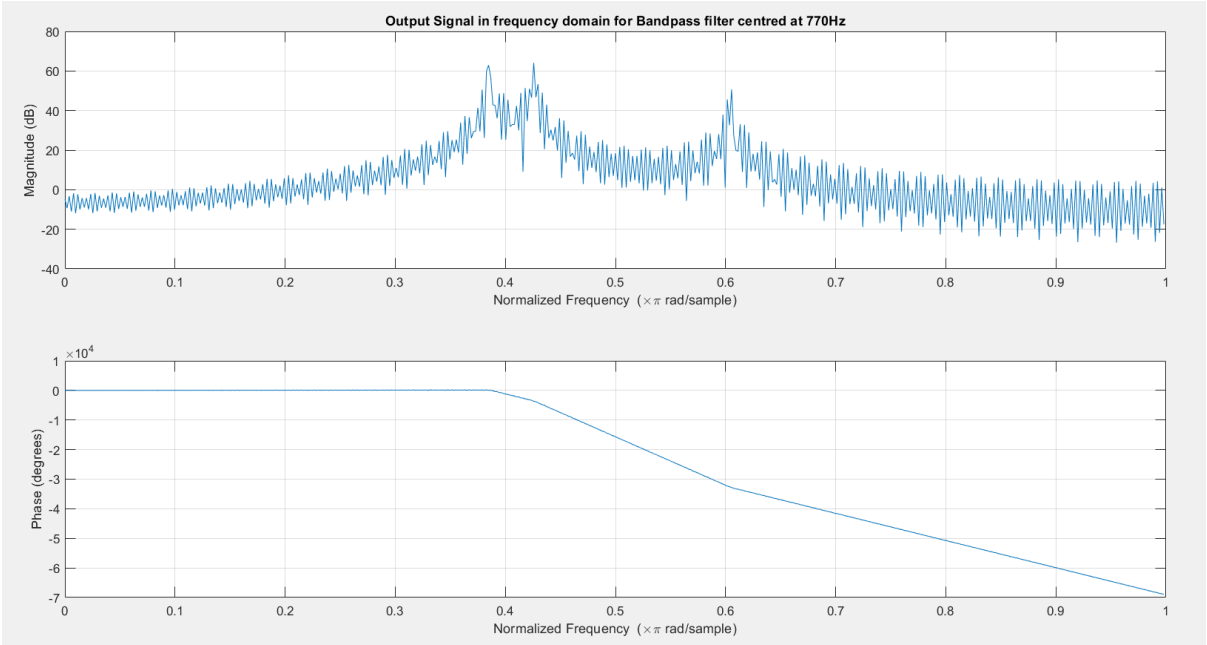


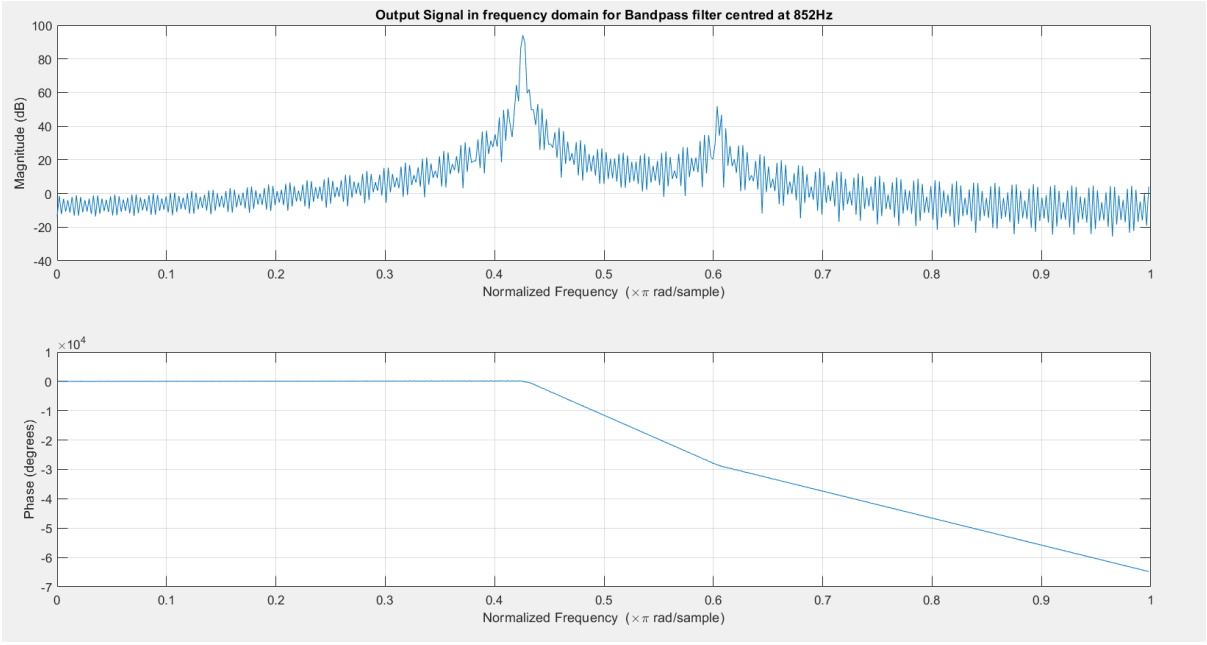


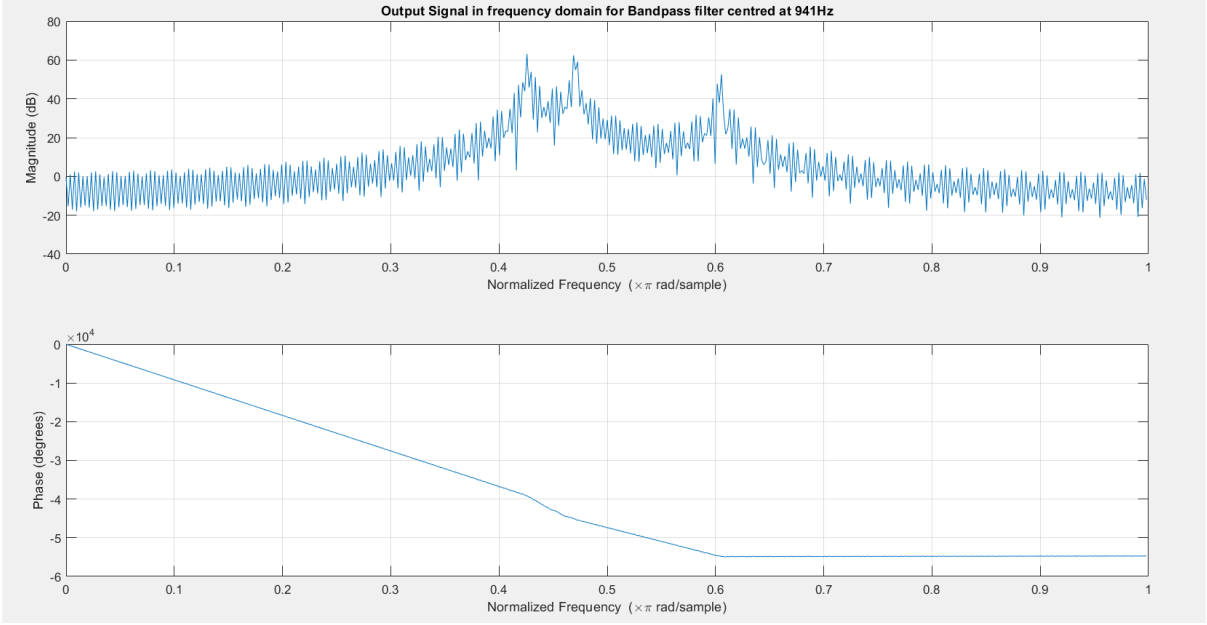

Input signal in frequency domain
X(ω) (absolute value)
Frequency in Hz

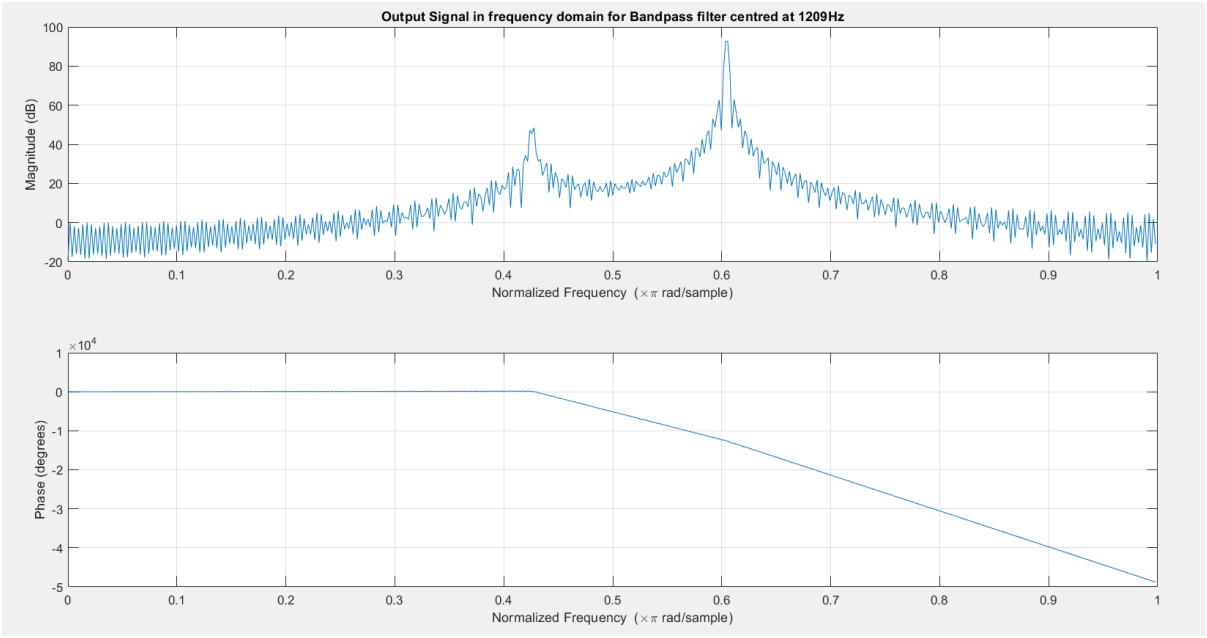

Input signal in frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase (degrees)
Normalized Frequency (×π rad/sample)

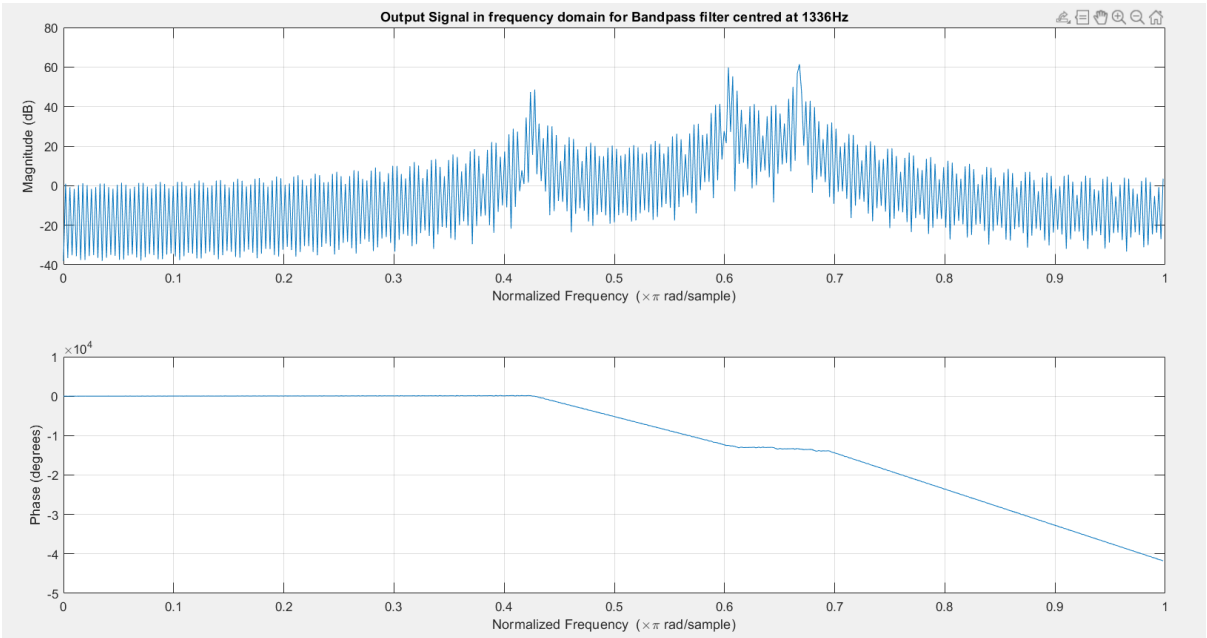

Output Signal in frequency domain for Bandpass filter centred at 697Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)

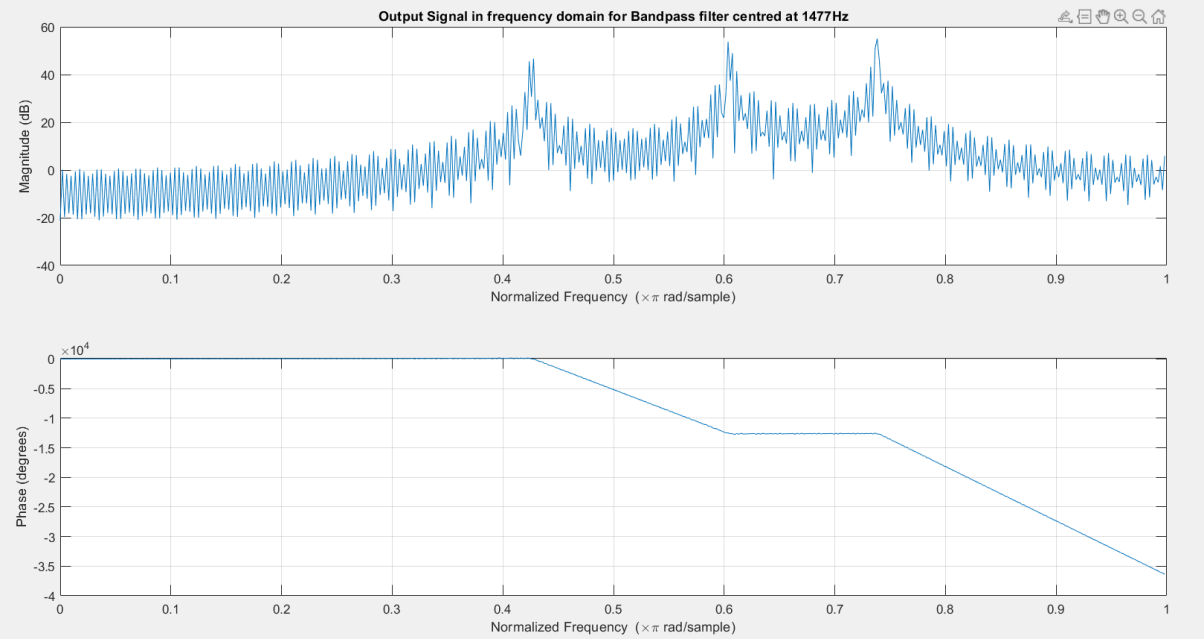

Output Signal in frequency domain for Bandpass filter centred at 770Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)

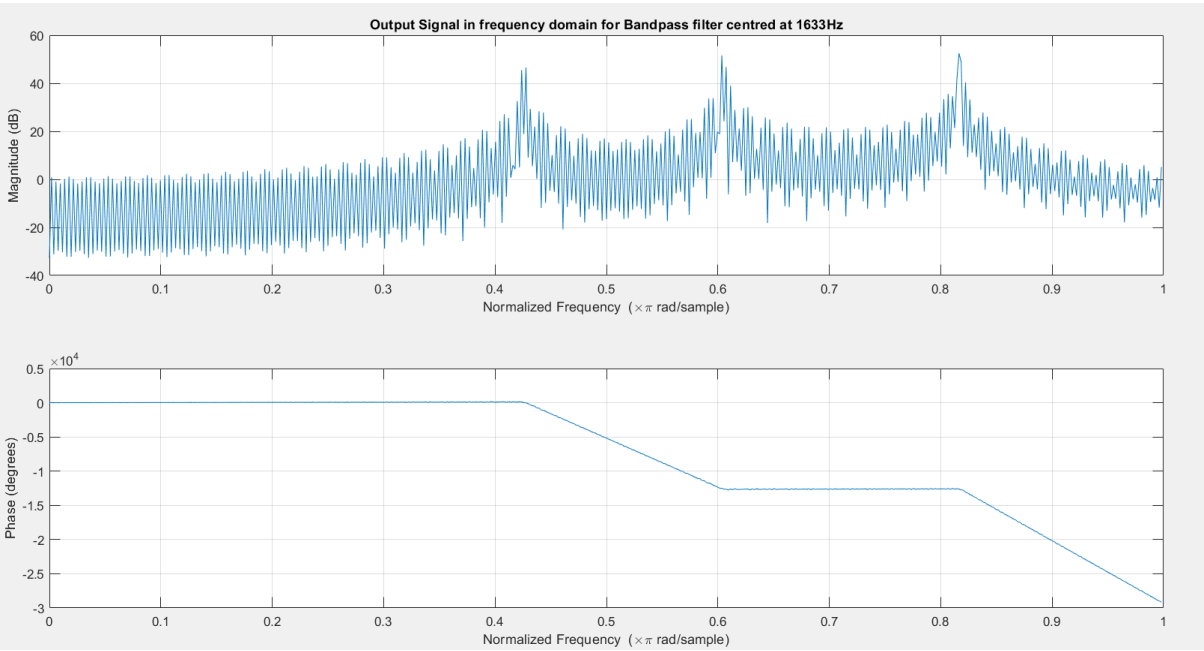

Output Signal in frequency domain for Bandpass filter centred at 852Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)


Output Signal in frequency domain for Bandpass filter centred at 941Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)


Output Signal in frequency domain for Bandpass filter centred at 1209Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)


Output Signal in frequency domain for Bandpass filter centred at 1336Hz
Magnitude (dB)
Normalized Frequency (×π rad/sample)
×10^4
Phase (degrees)
Normalized Frequency (×π rad/sample)





We see that the magnitude of the frequency response of the peaks is much higher in filters centred at frequencies present in the input signal. Further discussion will be done in lab report.

Look-up tables have been made for frequencies and symbols in the code. The formulae are apparent from the code, but will be discussed in the lab report as well.

Code:

```
clc
clear all
close all

L =  512;
Fs = 4000;
fc = [697, 770, 852, 941, 1209, 1336, 1477, 1633];
len = 0:L-1;
h_n = zeros(8,L);
y_n = zeros(8,L+Fs/10-1);
H = zeros(8,L);
W = zeros(8,L);
pwr = zeros(1,8);
t = 0:1/Fs:0.1-1/Fs;
for ii = 1:8
   h_n(ii,:) = cos(len*(2*pi*fc(ii)/Fs));
end

%Arranging matrix like this according to MATLAB indexing convention
mat_symbol = ['1' '4' '7' '*'; '2' '5' '8' '0'; '3' '6' '9' '#'; 'A' 'B' 'C' 'D'];

symbol = input('Which symbol do you want to send?\n', 's');

%%% Encoder %%%
idx = find(mat_symbol == symbol);
f1 = fc(floor((idx-1)/4)+1);
f2 = fc(4+mod(idx-1,4)+1);
x = cos(2*pi*f1*t)+cos(2*pi*f2*t);
%%% End %%%

figure();
sgtitle('Input Signal in Time Domain')
subplot(211);
stem(t(1:50*floor(Fs/f2)),x(1:50*floor(Fs/f2)))
grid on
xlabel('Time in seconds');ylabel('x(t)');title('Input signal in time domain (discrete representation)');
subplot(212);
plot(t(1:50*floor(Fs/f2)),x(1:50*floor(Fs/f2)))
grid on
xlabel('Time in seconds');ylabel('x(t)');title('Input signal in time domain (continuous representation)');


figure();
freq = -Fs/2:Fs/L:Fs/2-Fs/L;
plot(freq, abs(fftshift(fft(x, L))))
grid on
xlabel('Frequency in Hz');ylabel('X(\omega) (absolute value)');title('Input signal in frequency
domain');

figure();
freqz(x)
title('Input signal in frequency domain');
```

```
for ii = 1:8
    y_n(ii,:) = conv(x, h_n(ii,:));
    [H(ii,:), W(ii,:)] = freqz(y_n(ii,:), L);
    H(ii,:) = abs(H(ii,:));
    pwr(ii) = rms(y_n(ii,:))^2;
    figure();
    freqz(y_n(ii,:));
    title("Output Signal in frequency domain for Bandpass filter centred at " + num2str(fc(ii)) + "Hz")
end

%%% Decoder %%%
[max, idx] = maxk(pwr, 2);
idx = sort(idx);
result = mat_symbol(idx(2)-4, idx(1));
result
%%% Decoder end %%%
```