LAB #9

EE 224

1. *Introduction:* In this lab, we learnt about the practical application of sinusoidal signals, and design and implement a bandpass FIR filters. We used a touch-tone dialer to encode and decode the transition of sinusoidal information.

2. *PreLab*

2.1.2. On running through the following code:

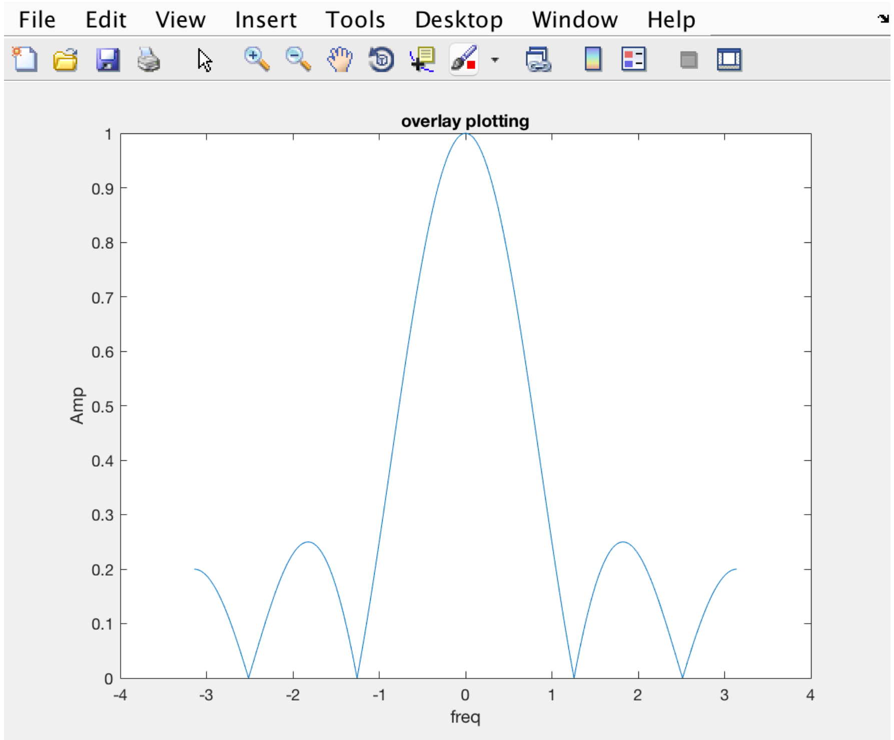
```
ftable = [1;2;3;4;5]*[80,110]
 fs = 8000;
 xx = [ ];
 %disp(?--- Here we go through the Loop ---?)
 keys = rem(3:12,10) + 1;
 for ii = 1:length(keys)
   kk = keys(ii);
   xx = [xx,zeros(1,400)];
   krow = ceil(kk/2);
   kcol = rem(kk-1,2) + 1;
   xx = [xx, cos(2*pi*ftable(krow,kcol)*(0:1199)/fs) ];
 end
 soundsc(xx,fs)
```

The value of the ftable obtained is:

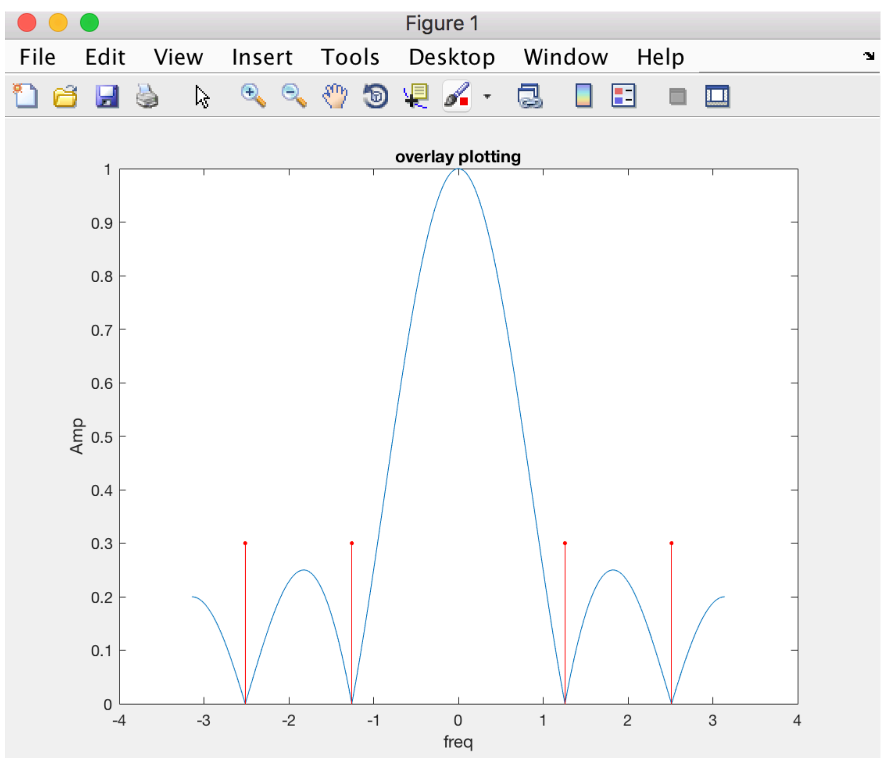
```
ftable =

    80   110
   160   220
   240   330
   320   440
   400   550
```

This program is somewhat inefficient even though the length of xx is small, and mostly unnoticeable, but due to allocation of large memory space.

2.2
a.



b.



3. *DTMF Synthesis*

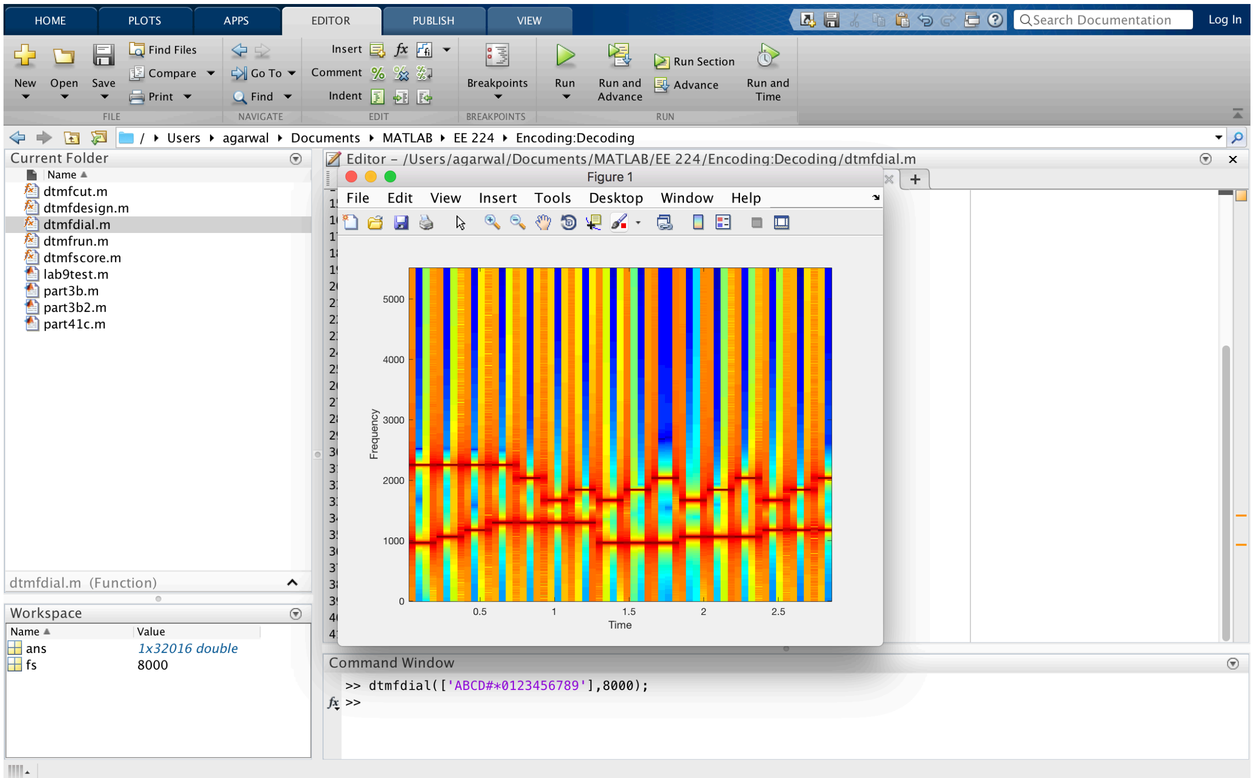
3.1

```
function xx = dtmfdial(keyNames,fs)
%DTMFDIAL Create a signal vector of tones which will dial
% a DTMF (Touch Tone) telephone system.
%
% usage: xx = dtmfdial(keyNames,fs)
% keyNames = vector of characters containing valid key names
% fs = sampling frequency
% xx = signal vector that is the concatenation of DTMF tones.
%
% Example function call
%  keyNames = ['5','1','5','2','3','B','*'];
%  fs  = 8000;
%  xx = dtmfdial(keyNames,fs);
%  To verify performance after running this routine, use:
%  spectrogram(xx,'yaxis',256,128,256,fs)
%  This will show that the correct signals have been encoded

%dtmf.keys is a 4 by 4 array for the phone keys
% the column and row locations give frequency information
dtmf.keys = ...
['1','2','3','A';
 '4','5','6','B';
 '7','8','9','C';
 '*','0','#','D'];

dtmf.colTones = ones(4,1)*[1209,1336,1477,1633];
dtmf.rowTones = [697;770;852;941]*ones(1,4);

xx = [];
for x= 1:length(keyNames)
    m=keyNames(x);
    [i,j]=find(m == dtmf.keys);
    xx=[xx,zeros(1,400)];
    row=dtmf.rowTones(i,j);
    col=dtmf.colTones(i,j);
    xx=[xx,cos(2*pi*row*(0:1600)/fs)+cos(2*pi*col*(0:1600)/fs)];
end

soundsc(xx,fs);
specgram(xx,1024,11025);
```

Using the command

>> dtmfdial (['ABCD#*0123456789'],8000);

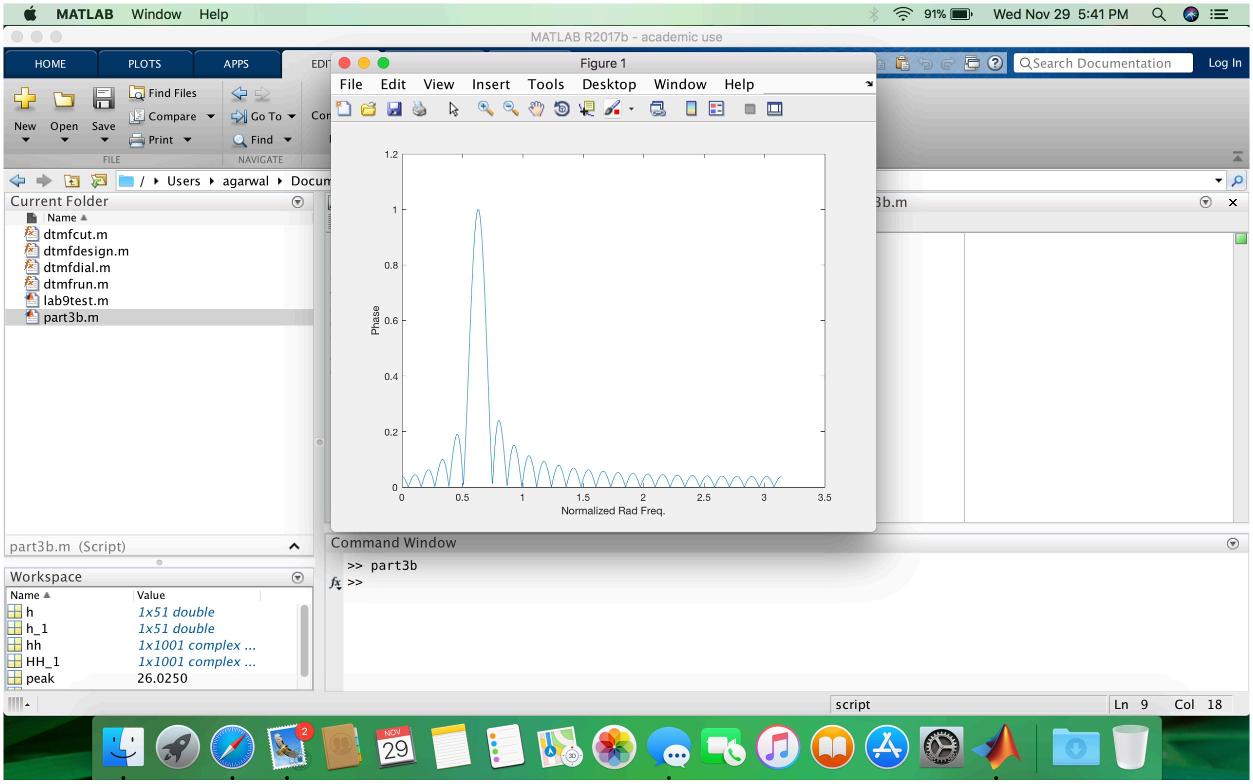
the following spectrogram is obtained:



3.2

(a) .

```
x =0:(pi/1000):pi;
h=cos(0.2*pi*(0:50));
hh=freqz(h,1,x);
peak=max(abs(hh));
h_1=1/peak*cos(0.2*pi*(0:50));
HH_1=freqz(h_1,1,x);
plot(x,abs(HH_1));
xlabel ('Normalized Rad Freq.');
ylabel ('Phase');
```



(b) .

To find the width of the bandpass,

```
x =0:(pi/1000):pi;
h=cos(0.2*pi*(0:50));
hh=freqz(h,1,x);
peak=max(abs(hh));
h_1=1/peak*cos(0.2*pi*(0:50));
HH_1=freqz(h_1,1,x);
plot(x,abs(HH_1));
xlabel ('Normalized Rad Freq.');
ylabel ('Phase');

bandpass=find(abs(HH_1)>=0.707);
width1=x(bandpass(1));
width2=x(length(bandpass)+bandpass(1)-1);
width=width2-width1;
```

This gives us the width = 0.1037, with width1 = 0.5781, & width2 = 0.6817,

(c) .

The range of the frequency component that would pass from this filter will be from,

0.5781*8000 = 4624.8 rad/sec, to
0.6817*8000 = 5453.6 rad/sec.

4. *DTMF Decoding*

4.1

```
function hh = dtmfdesign(fb, L, fs)
%DTMFDESIGN
% hh = dtmfdesign(fb, L, fs)
% returns a matrix (L by length(fb)) where each column contains
% the impulse response of a BPF, one for each frequency in fb
% fb = vector of center frequencies
% L = length of FIR bandpass filters
% fs = sampling freq
%
% Each BPF must be scaled so that its frequency response has a
% maximum magnitude equal to one.
hh=[];

 for i = 1:length(fb)
     h=cos((2*pi*fb(i)*(0:L-1))/fs);
     [H,W]=freqz(h);
     B=1/max(abs(H));
     h=B*cos((2*pi*fb(i)*(0:L-1))/fs);
       plot(W,abs(H),'color',[1-i/10 i/10 1]);
     hold on;
     hh=[hh,h'];
 end
 title('dtmfdesign')
 xlabel('Freq');
 ylabel('Amp')
 grid on
```

For L=40:

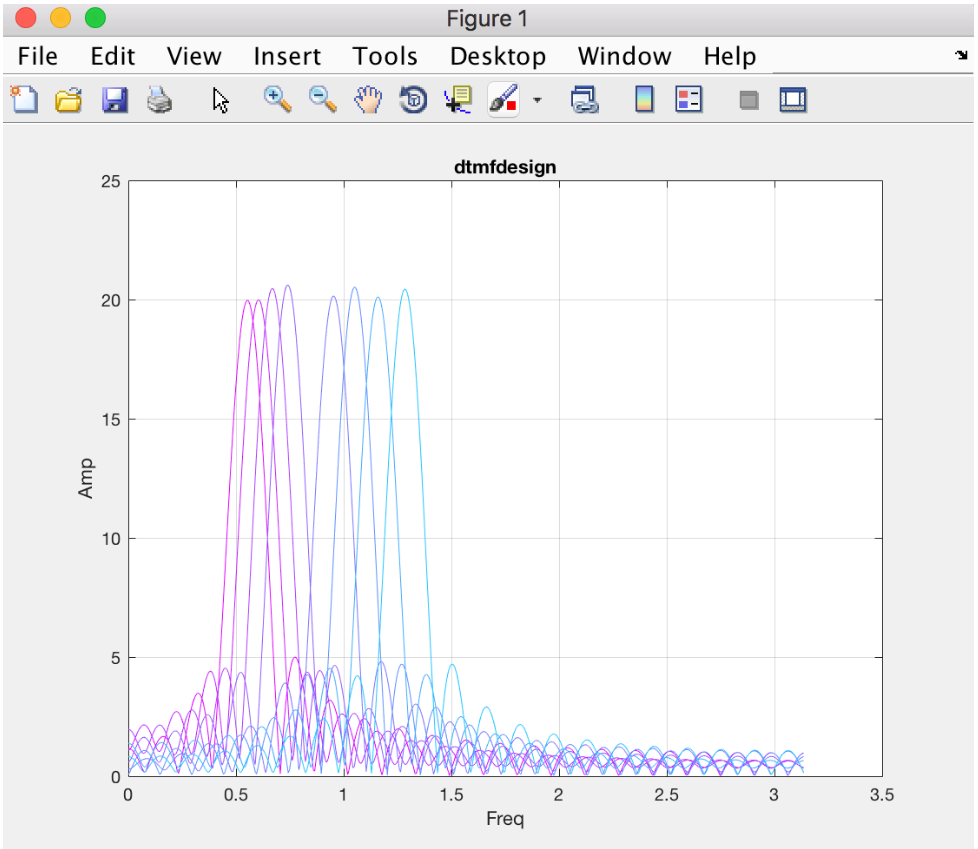
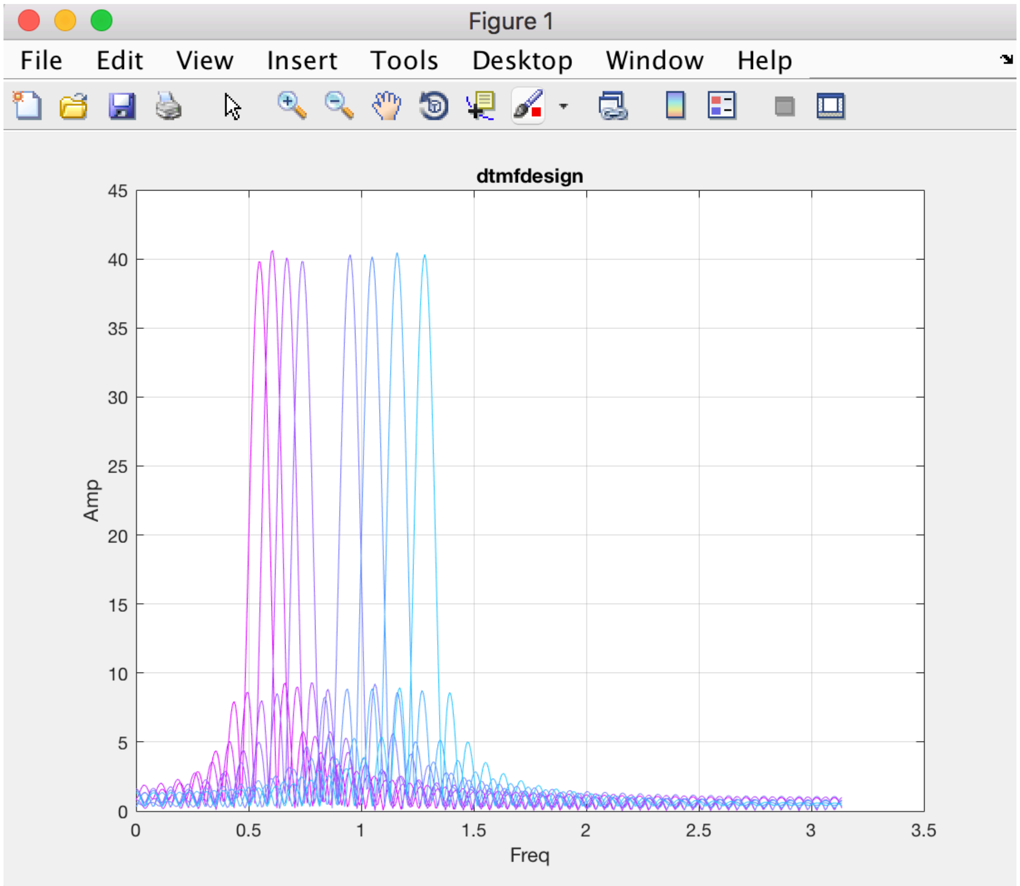


Figure 1
File Edit View Insert Tools Desktop Window Help
dtmfdesign
Amp
Freq
0
5
10
15
20
25
0.5
1
1.5
2
2.5
3
3.5

For L=80:



No, not each passband is narrow enough for only one frequency component to lie in.

The nearest corner frequency of 697 and 770 are hardest to meet the specs.

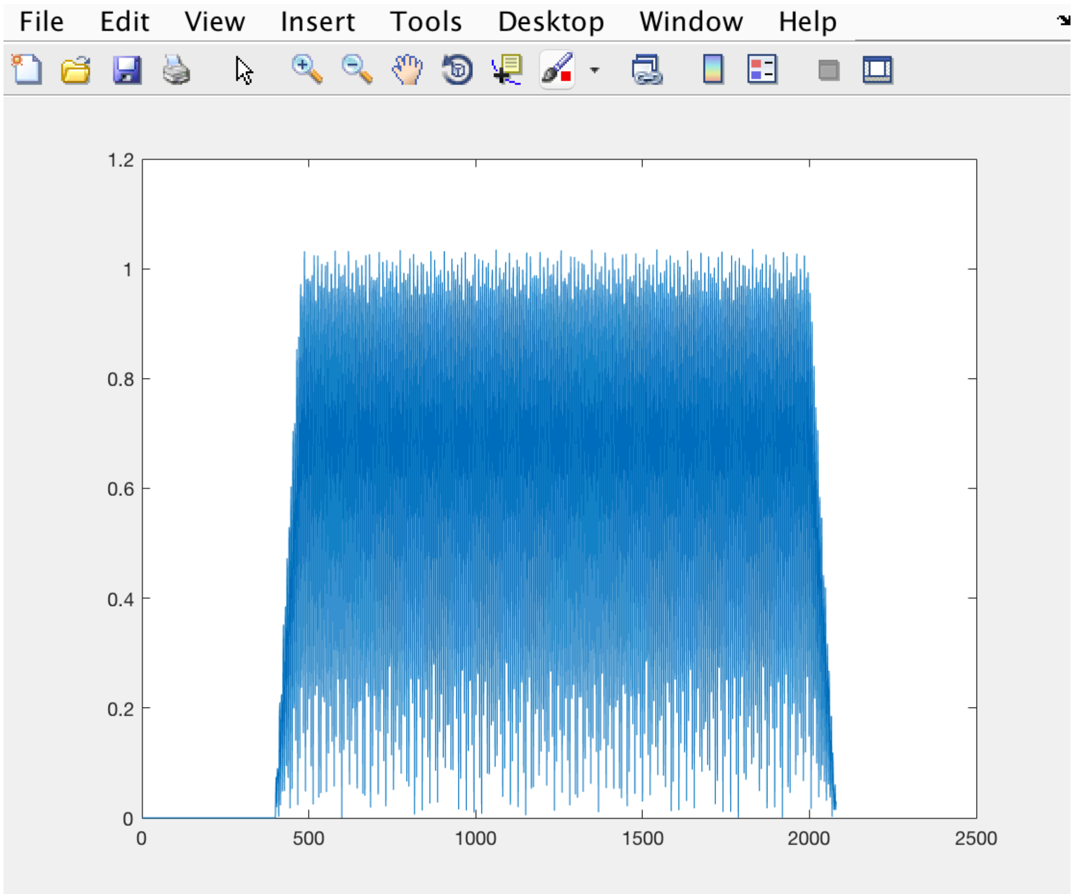
4.2.

```
function sc=dtmfscore(xx,hh)
xx = xx*(2/max(abs(xx)));
Y = conv(xx,hh);
plot(abs(Y));
if (max(abs(Y)))>=0.59
    sc=1;
else
    sc=0;
end
```

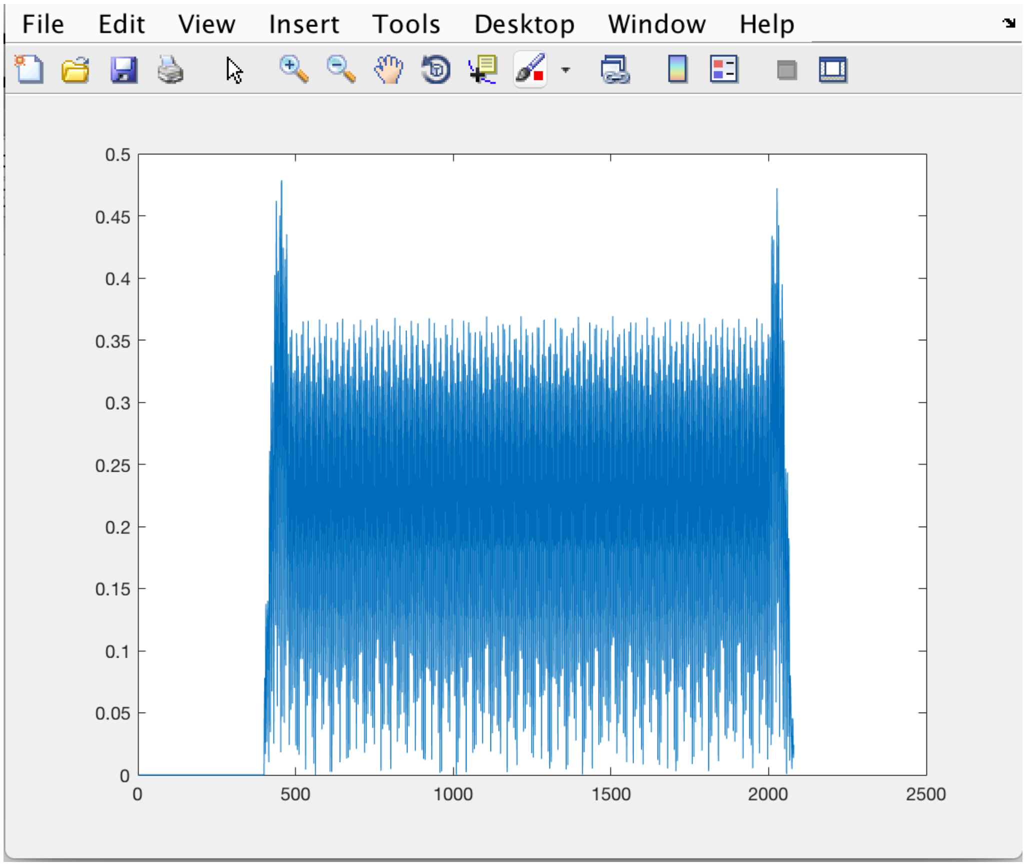
The maximum value for H(ejω^) should be 1, because to achieve a scoring threshold of 0.59.

After debugging through my score program, the following matched and mismatched graphs were obtained:

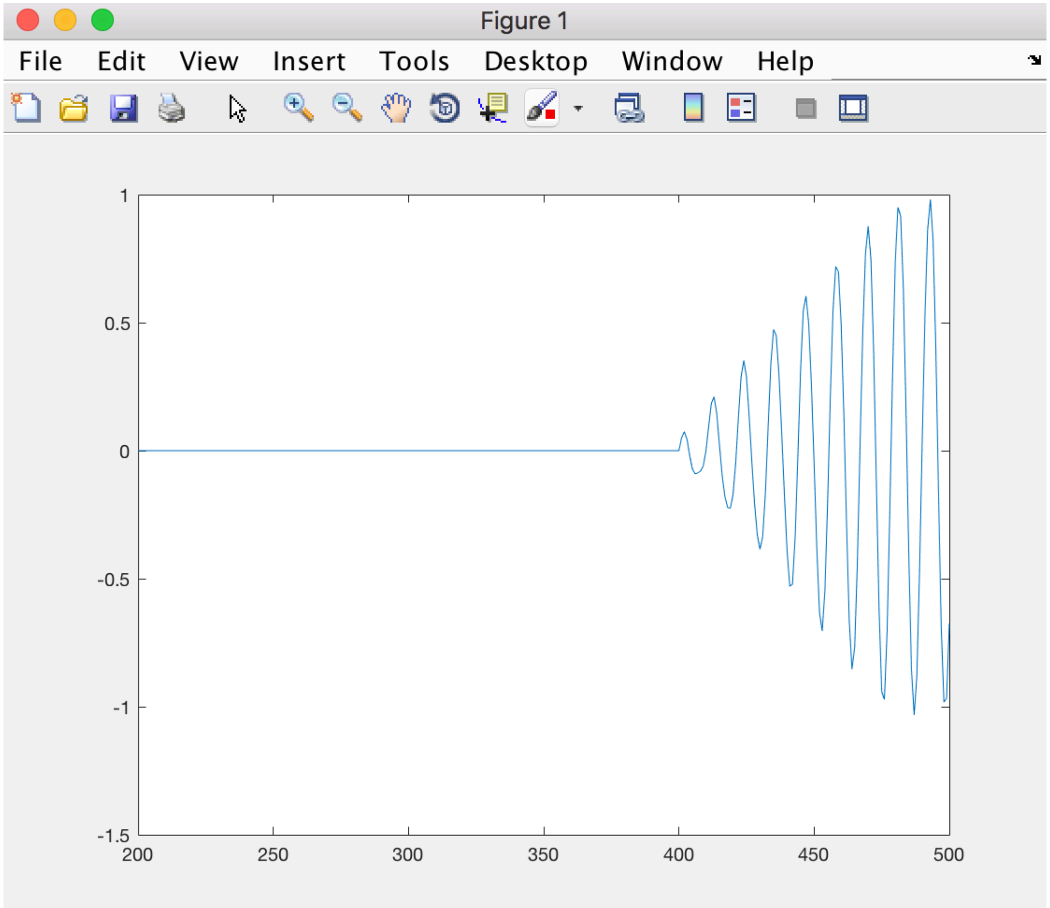
When ans = 1:



When ans = 0:



On 200-500 points scale:



4.3

```
function keys = dtmfrun(xx,L,fs)

%DTMFRUN keys = dtmfrun(xx,L,fs)
% returns the list of key names found in xx.
% keys = array of characters, i.e., the decoded key names
%
% Inputs:
%   xx = DTMF waveform
%   L = filter length
%   fs = sampling freq
%

% Initialize key arrays and frequencies
dtmf.keys = ...
['1','2','3','A';
 '4','5','6','B';
 '7','8','9','C';
 '*','0','#','D'];
```

```
center_freqs = [697,770,852,941,1209,1336,1477,1633];

hh = dtmfdesign(center_freqs,L,fs );

[nstart,nstop] = dtmfcut(xx,fs); %<--Find the beginning and end of tone bursts

keys = [];
M=zeros(1,8);

for kk=1:length(nstart)
   x_seg = xx(nstart(kk):nstop(kk));
   for i=1:8
      M(i)=dtmfscore(x_seg, hh(:,i));
   end
   ind=find(M==1);

   if (length(ind)>2)
     keys = [keys,'-1'];
   else
      row_ind = find(M(1:4)==1);
      col_ind = find(M(5:8)==1);
      keys = [keys,dtmf.keys(row_ind,col_ind)];
   end;
end
end
```

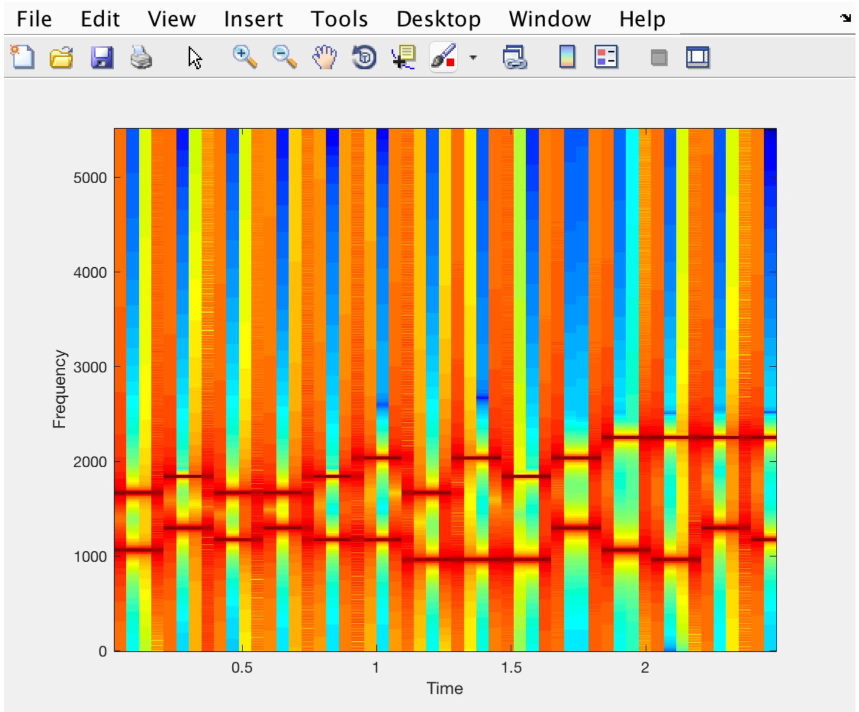
On the running the following command:

```
>> fs=8000;
>> tk=['4','0','7','*','8','9','1','3','2','#','B','A','D','C'];
>> xx=dtmfdial(tk,fs);
>> soundsc(xx,fs)
>> L=80;
>> dtmfrun(xx,L,fs)
```

The following result was obtained:

```
ans =

   '407*89132#BADC'
```

The spectrogram of the signal from dtmfdial:


File Edit View Insert Tools Desktop Window Help
Frequency
Time
0
1000
2000
3000
4000
5000
0.5
1
1.5
2