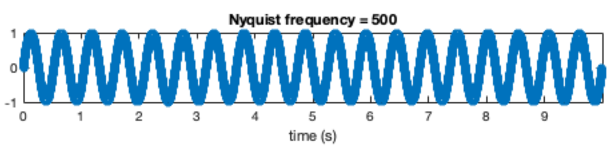
Contents


```
%%%%% ASSIGNMENT02 (2023)
%%%%% ALIASING

%%%%% PART 1 goal is to visualize aliasing and discover the relationship between the original signal frequency, Nyquist frequency, and aliased frequency.  N
```

1: Construct a 1.9 Hz sinusoid for a 10 s signal duration (i.e., 19 full cycles). Plot this sinusoid with an initial sample rate of 1000 Hz (i.e., N = 10,000 samples). What is its Nyquist frequency?

```
f = 1.9;
N = 10000;
sps = 1000;
t = (0:N-1)/sps;
w = f*2*pi;
x = t*w;
maxt = max(t);

figure(1); clf
subplot(4,1,1) % now plot the original sinuosid
y = sin(x);
plot(t,y,'-o')
xlabel('time (s)')
xlim([0 maxt])
Ny1 = sps/2;
title(['Nyquist frequency = ' num2str(Ny1)])
```

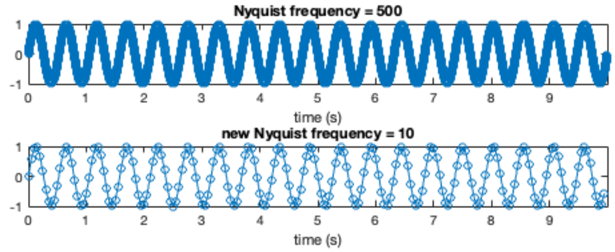


2: Downsample the sinusoid from part 1 by a factor of 50 while keeping the signal duration 10 s. (Hint? you can easily downsample by passing the notation (1:50:end) as indices to your vector. What is the new Nyquist frequency of your sample? What is the frequency of the plotted signal?

```
subplot(4,1,2)
dec2 = 50;
y = sin(x);
plot(t(1:dec2:end),y(1:dec2:end),'-o')
xlabel('time (s)')
xlim([0 maxt])
Ny2 = sps/2/dec2
title(['new Nyquist frequency = ' num2str(Ny2)])
```

```
Ny2 =
```

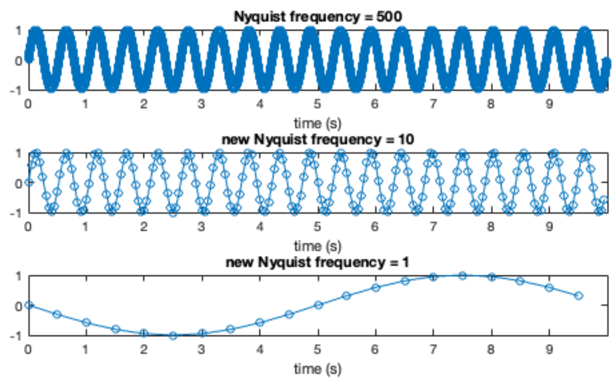
```
10
```



3: Downsample the sinusoid from step 1 by a factor of 500 and plot the new data. What is new Nyquist frequency and what is the (aliased) frequency of the plotted signal (should be easy to estimate off of the graph)?

```
subplot(4,1,3)
dec3 = 500;
y = sin(x);
plot(t(1:dec3:end),y(1:dec3:end),'-o')
xlabel('time (s)')
xlim([0 maxt])
Ny3 = sps/2/dec3
title(['new Nyquist frequency = ' num2str(Ny3)])
```

```
Ny3 =

     1
```

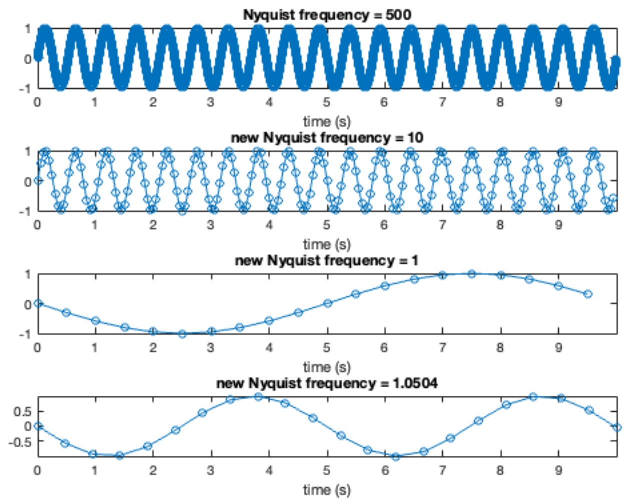


4: Downsample the sinusoid from part 1 by a factor of 476 and plot the new data. What is new Nyquist frequency and what is the frequency of the plotted signal?

```
subplot(4,1,4)
y = sin(x);
dec4 = 476;
```

```
plot(t(1:dec4:end),y(1:dec4:end),'-o')
xlabel('time (s)')
axis tight
Ny4 = sps/2/dec4
title(['new Nyquist frequency = ' num2str(Ny4)])

% 5: Based upon your findings in 3 and 4 derive an explicit expression for the aliased frequency as a function of Nyquist frequency and original frequency.
% results above: 1.9 Hz folds to .1 Hz for Nyquist = 1
%                1.9 Hz folds to .2 Hz for Nyquist = 1.05
% leads to (F_alias + F)/2 = F_Nyquist or F_alias = 2*F_Nyquist - F
% where F is actual frequency is 1.9 Hz
```

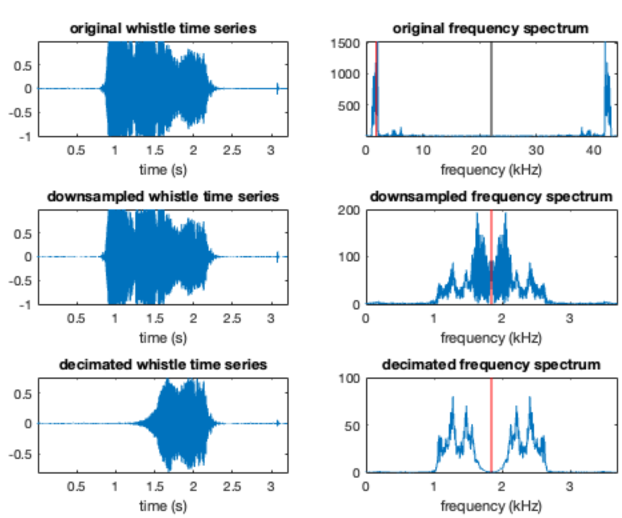
```
Ny4 =

    1.0504
```




```
%%%%% PART 2 demonstrates aliasing using sound wave recordings and two different methods of downsampling.  Note that exercises 1-3 below could be convenient
% note also that this cell plots spectra (which are not requested in the
% homework assignment)

figure(2); clf
working_directory = '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/';

% 1: Load in data file whistle.mat located at course website. Plot the time series using an appropriate time axis (in s) and the specified sample rate.  Use
cd(working_directory)
load whistle
ts = (1:length(Y))/Fs;

subplot(3,2,1)
plot(ts,Y)
%sound(Y,Fs)
axis tight
title('original whistle time series')
xlabel('time (s)')
Fs_nyquist = Fs/2;

subplot(3,2,2) % plot corresponding frequency spectrum
n = 2^nextpow2(length(Y));
A = abs(fft(Y,n));
fs = ((0:n-1)/n)*Fs;
plot(fs/1000,A)
xlabel('frequency (kHz)')
hold on
Fn = Fs/2;
axis tight
plot([Fn Fn]/1000,ylim,'k-')
plot([Fn Fn]/1000/12,ylim,'r-')
title('original frequency spectrum')

% 2: Downsample the sound data by a factor of 12 and plot it.  Again, use sound to play your downsampled file.  What is the new Nyquist frequency?  Think ab
subplot(3,2,3)
res = 12;
Yres = Y(1:res:end);
tres = ts(1:res:end);
```

```
%sound(Yres,Fs/res);
plot(tres,Yres)
axis tight
title('downsampled whistle time series')
xlabel('time (s)')

subplot(3,2,4) % plot corresponding frequency spectrum
nres = 2^nextpow2(length(Yres));
Ares = abs(fft(Yres,nres));
fsres = ((0:nres-1)/nres)*Fs/res;
plot(fsres/1000,(Ares))
%plot(fsres/1000-max(fsres)/1000/2,fftshift(Ares))
xlabel('frequency (kHz)')
hold on
Fnres = Fs/res/2;
%plot([Fn Fn]/1000,ylim,'r-')
plot([Fnres Fnres]/1000,ylim,'r-')
title('downsampled frequency spectrum')
axis tight

% 3: Now resample the original sound file by using the MATLAB function decimate(Y,12).  Plot it on an appropriate time axis and play it at an appropriate sa
subplot(3,2,5)
dec = 12;
Ydec = decimate(Y,dec);
tdec = ts(1:dec:end);
%sound(Ydec,Fs/dec);
plot(tdec,Ydec)
axis tight
title('decimated whistle time series')
xlabel('time (s)')

subplot(3,2,6) % plot corresponding frequency spectrum
ndec = 2^nextpow2(length(Ydec));
Adec = abs(fft(Ydec,ndec));
fsdec = ((0:ndec-1)/ndec)*Fs/dec;
plot(fsdec/1000,(Adec))
%plot(fsdec/1000-max(fsdec)/1000/2,fftshift(Adec))
xlabel('frequency (kHz)')
hold on
Fndec = Fs/dec/2;
%plot([Fn Fn]/1000,ylim,'r-')
plot([Fndec Fndec]/1000,ylim,'r-')
title('decimated frequency spectrum')
axis tight

% print figure
set(gcf,'paperposition',[0 0 8 5])
print_directory = '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
print('-djpeg90','-r300',[print_directory 'aliasing_figure'])
```

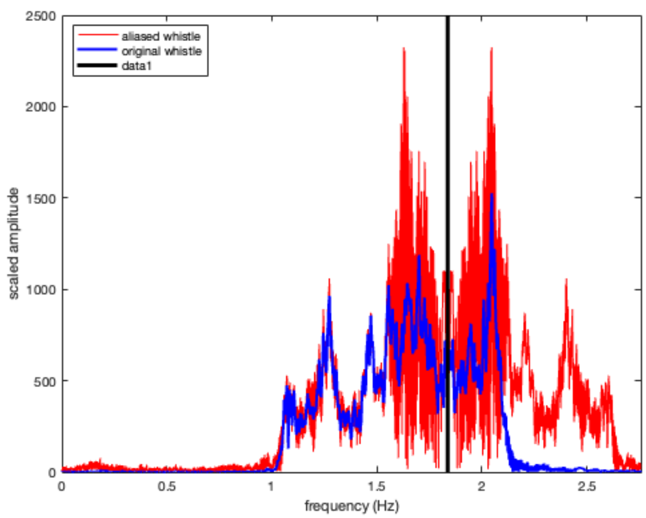
```
print_directory =

    '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
```



comparison of aliased and non-aliased waveforms

```
figure(3); clf

subplot(1,1,1)
plot(fsres/1000,(Ares)*12,'r')
hold on
plot(fs/1000,A,'b','linewidth',2)
xlabel('frequency (Hz)')
ylabel('scaled amplitude')
xlim([0 Fnres]*1.5/1000)
legend('aliased whistle','original whistle','location','northwest')
plot(Fnres/1000+[0 0],ylim,'k','linewidth',3)

% print figure
set(gcf,'paperposition',[0 0 5 3.5])
print_directory = '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
print('-djpeg90','-r300',[print_directory 'aliased_whistle'])
```

```
print_directory =

    '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
```

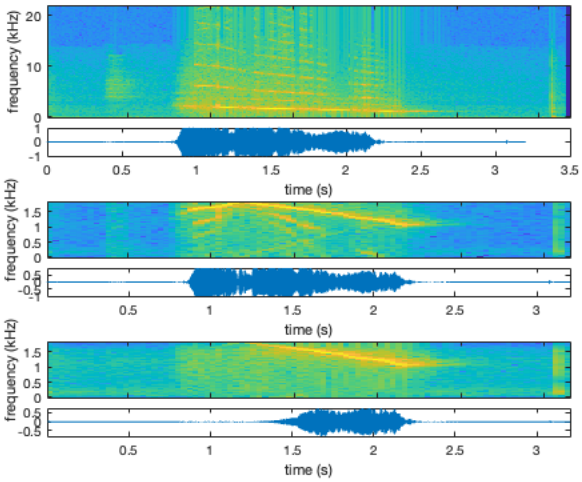


make spectrograms for part 2 of the homework assignment

```
figure(4); clf
axes('position',[.2 .6 .7 .05])
plot(ts,Y)
xlabel('time (s)')

axes('position',[.2 .67 .7 .2])
[B,F,T] = spectrogram(Y,1024,512,1024,Fs);
imagesc(T,F/1000,log10(abs(B)))
set(gca,'ydir','normal')
ylabel('frequency (kHz)')
set(gca,'xticklabel',[])

axes('position',[.2 .35 .7 .05])
plot(tres,Yres)
axis tight
xlabel('time (s)')

axes('position',[.2 .42 .7 .1])
[B,F,T] = spectrogram(Yres,256,128,1024,Fs/res);
imagesc(T,F/1000,log10(abs(B)))
set(gca,'ydir','normal')
ylabel('frequency (kHz)')
set(gca,'xticklabel',[])

axes('position',[.2 .1 .7 .05])
plot(tres,Ydec)
axis tight
xlabel('time (s)')
```

```
axes('position',[.2 .17 .7 .1])
[B,F,T] = spectrogram(Ydec,256,128,1024,Fs/dec);
imagesc(T,F/1000,log10(abs(B)))
set(gca,'ydir','normal')
ylabel('frequency (kHz)')
set(gca,'xticklabel',[])


% print figure
set(gcf,'paperposition',[0 0 5 8])
print_directory = '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
print('-djpeg90','-r300',[print_directory 'aliasing_spectrograms'])
```

```
print_directory =

    '/Users/jeffreybjohnson/Documents/COURSES/BSU/2023/DSP/ASSIGNMENT02/'
```



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