



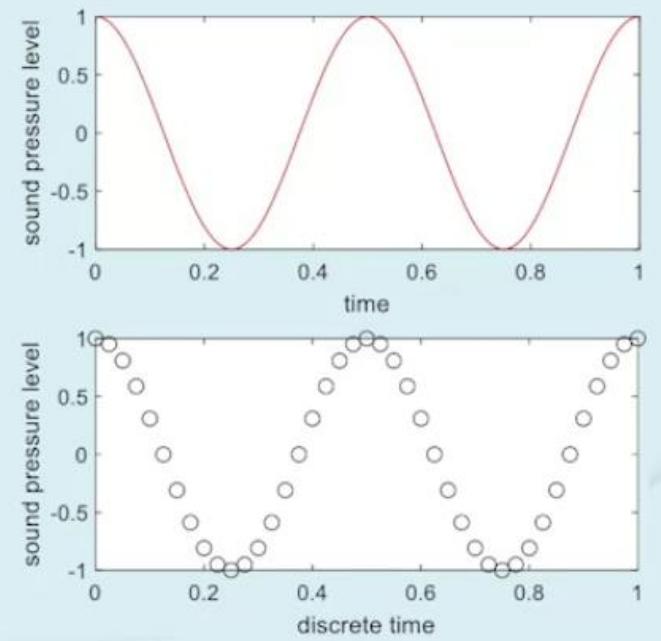
Introduction to Data, Signal, and Image Analysis with MATLAB®

**Lesson 3.1 Signals as time
dependent data**

Jack Noble



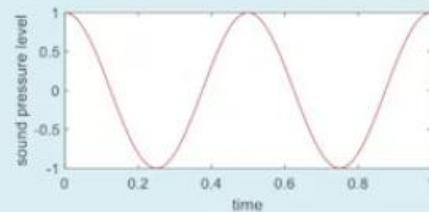
We also have discrete time signals,



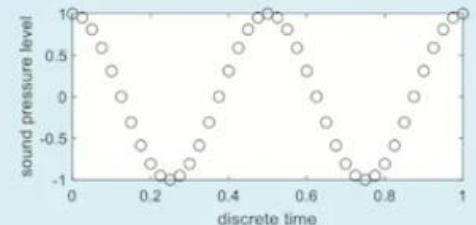


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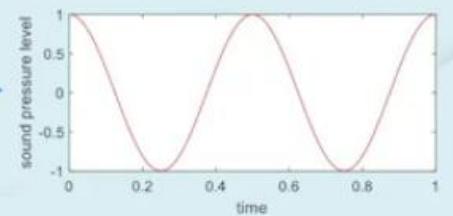
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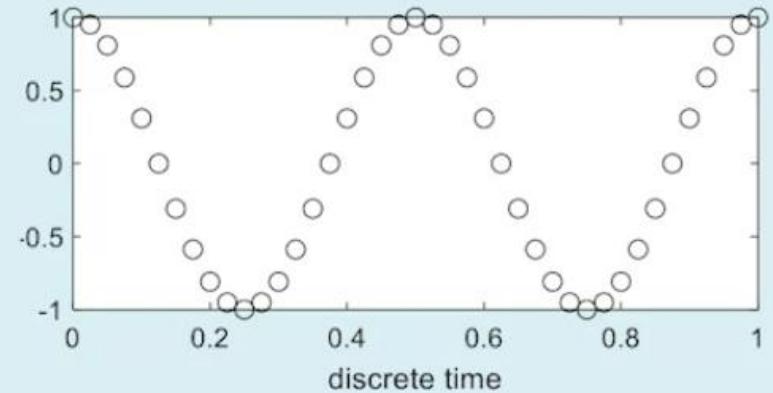
Sampling (Analog to digital conversion)



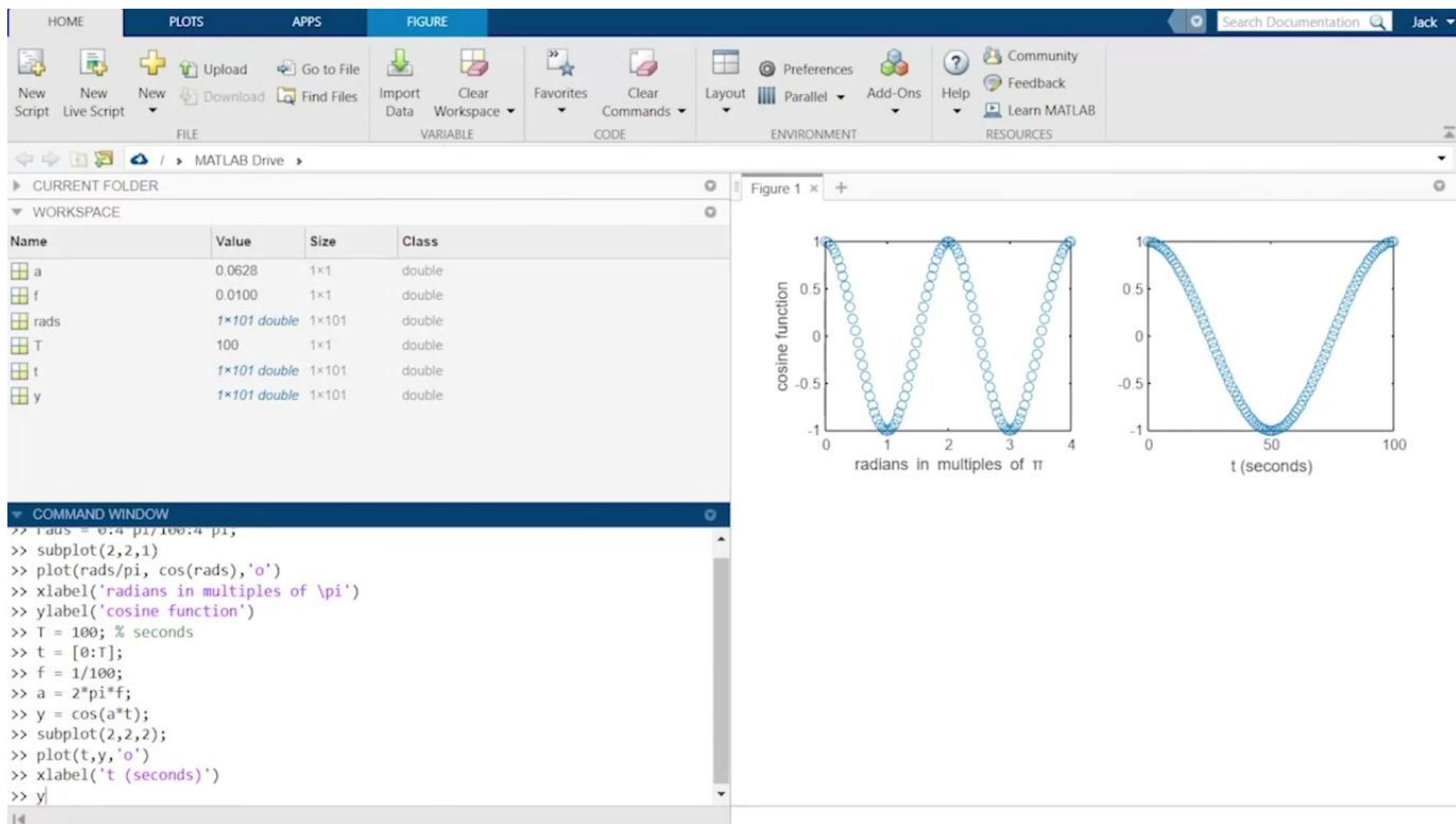
Digital to analog conversion

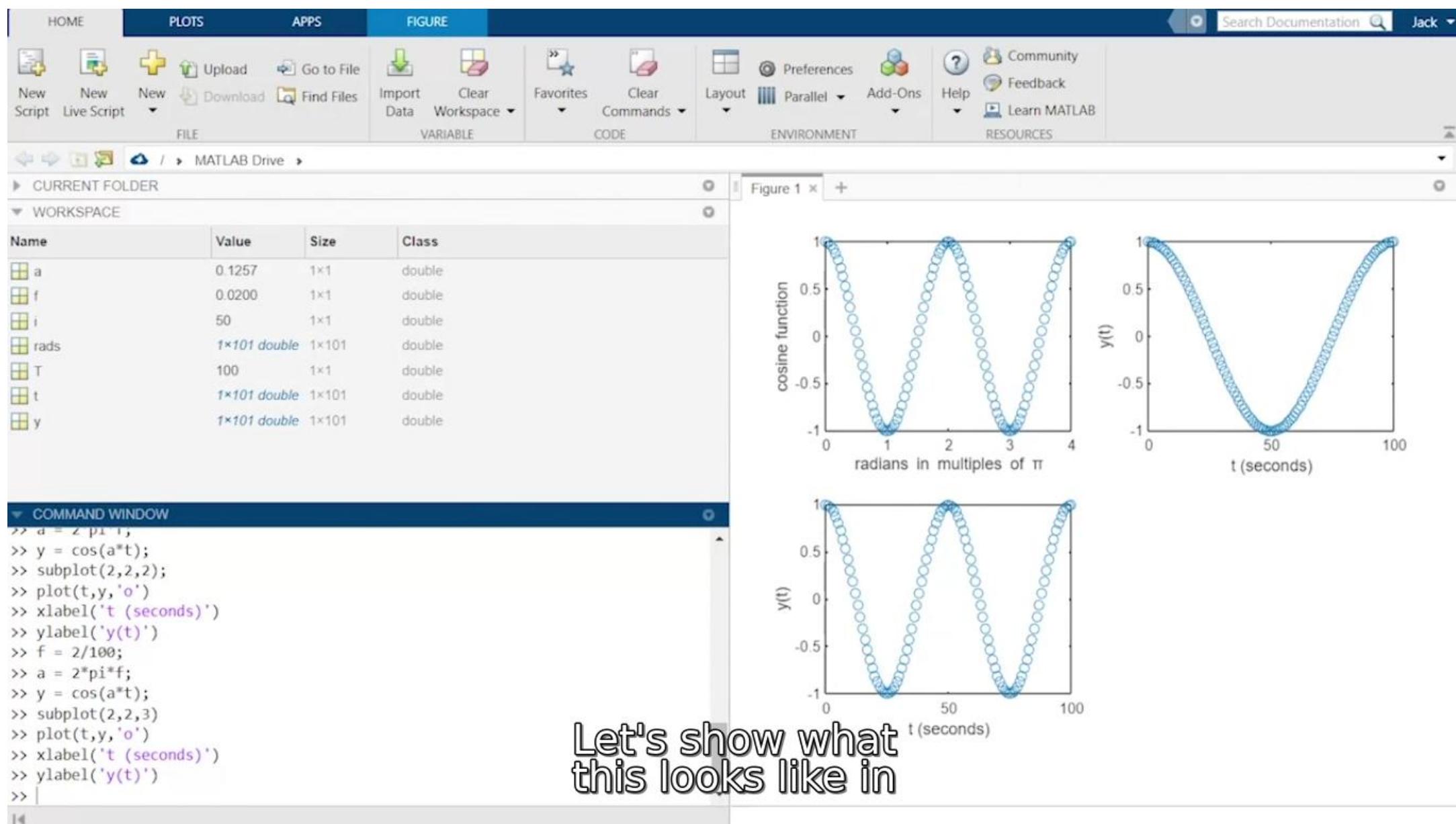


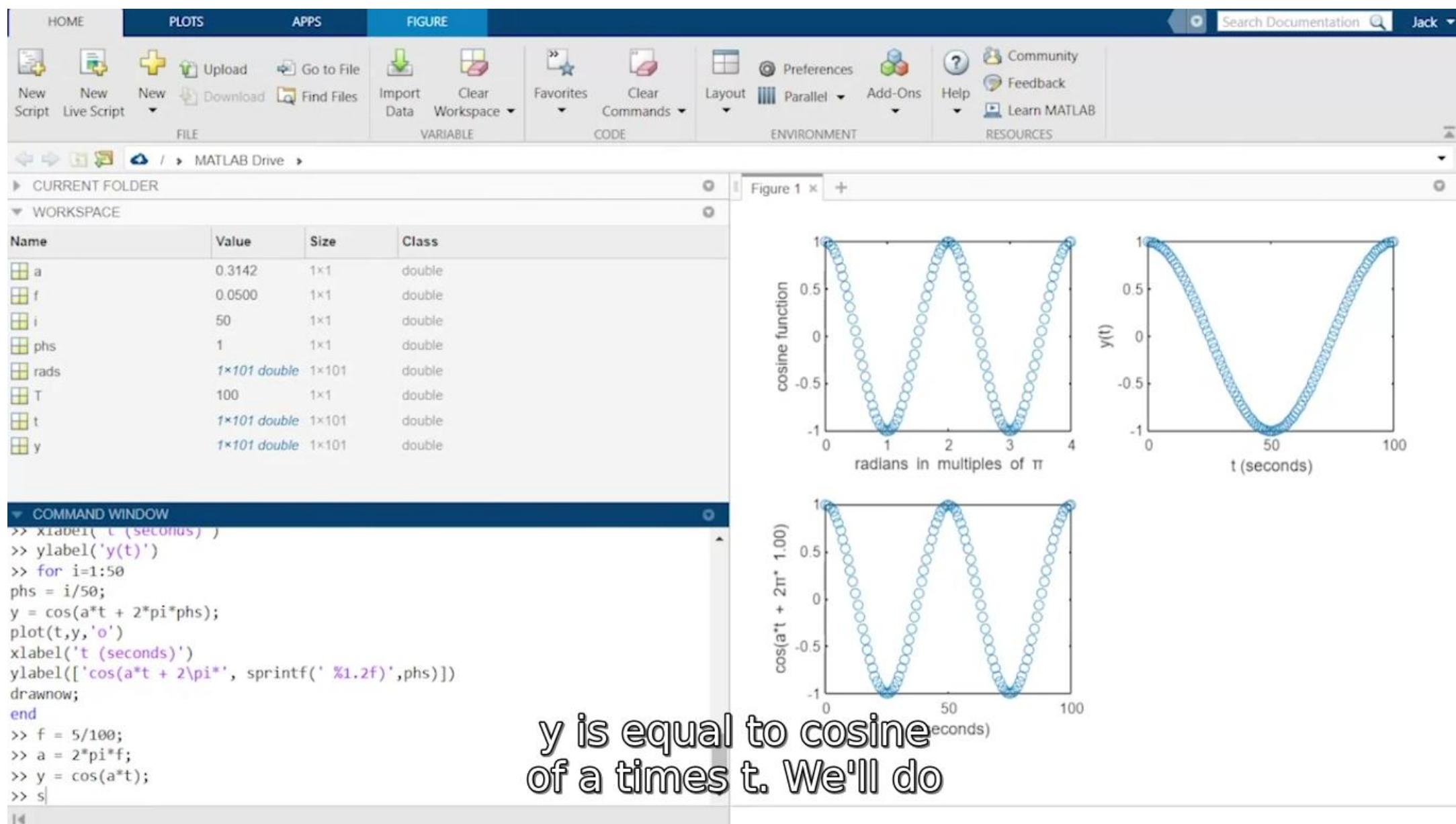
This microphone is sampling

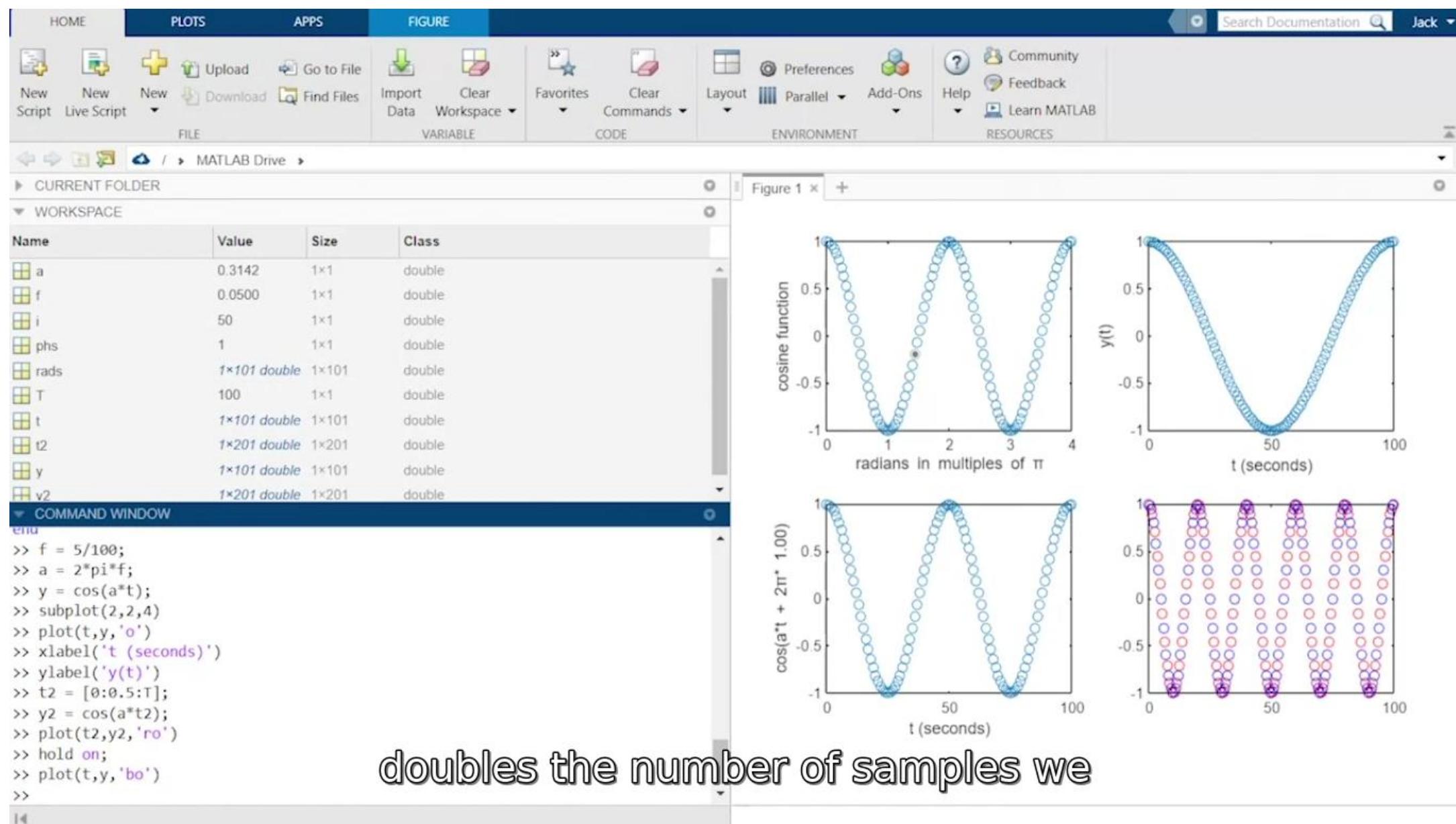


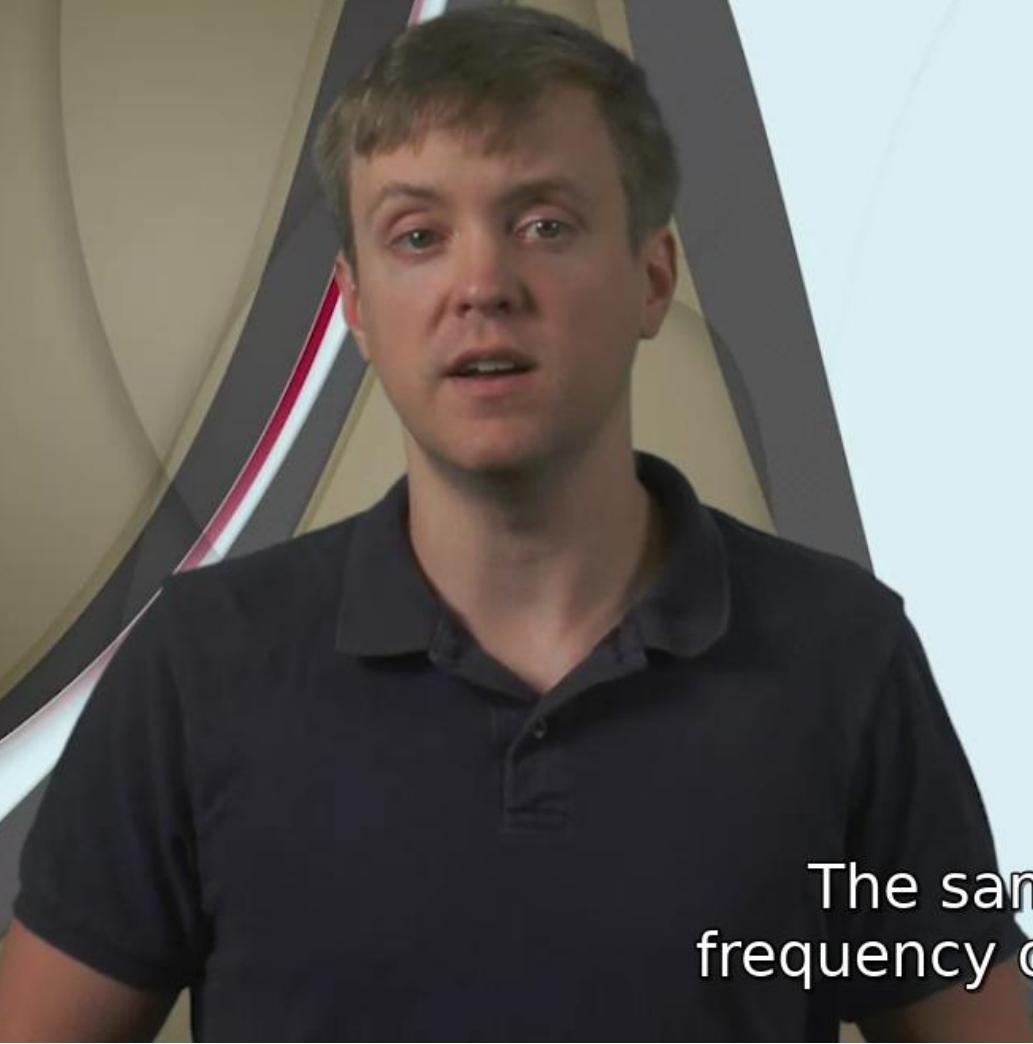
For example, instead
of just the Dow Jones,



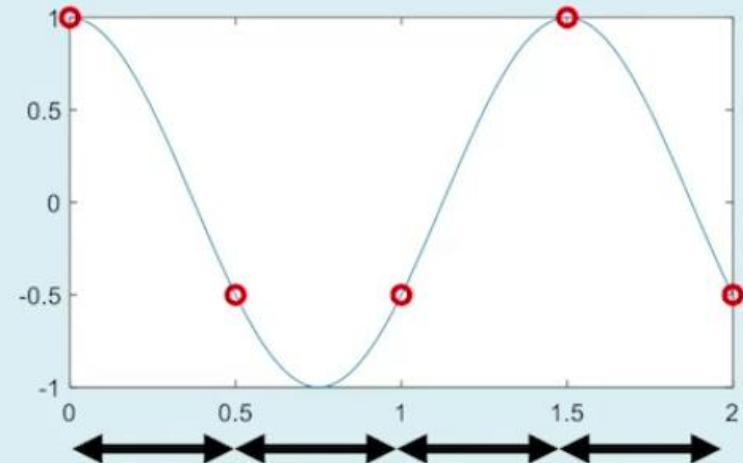








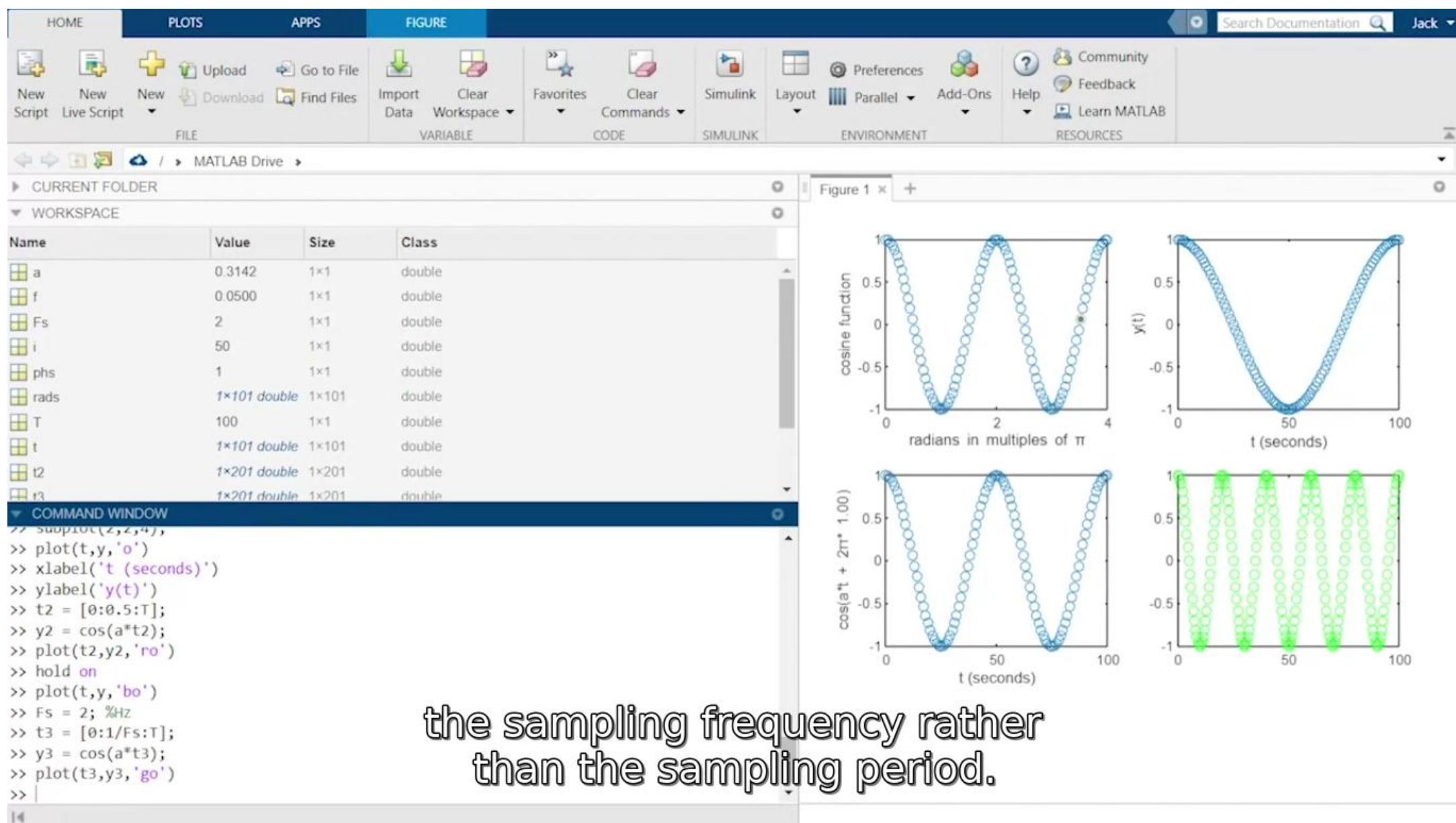
The sampling frequency of a signal



Sampling period: $T_S = 0.5$ seconds

Sampling frequency: $F_S = \frac{1}{T_S} = 2$ Hz

$$\text{Hz} = \left(\frac{\# \text{ samples}}{\text{second}} \right)$$



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WORKSPACE

Name	Value	Size	Class
a	0.1257	1x1	double
f	0.0200	1x1	double
Fs	[1, 0.2500, 0...]	1x4	double
T	100	1x1	double

COMMAND WINDOW

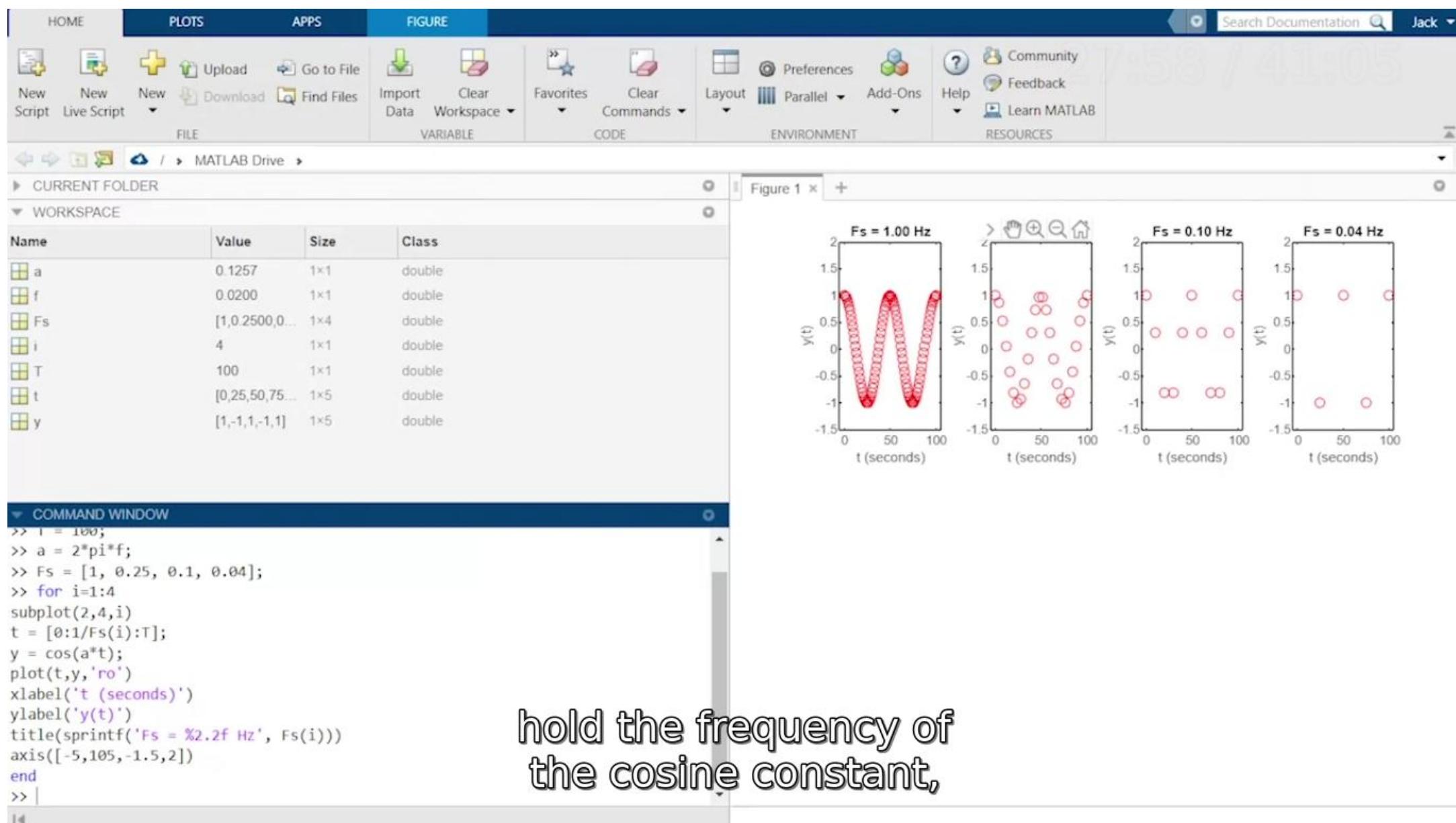
```
>> f = 2/100;
>> T = 100;
>> a = 2*pi*f;
>> Fs = [1, 0.25, 0.1, 0.04];
>> for i=1:4
    subplot(2,4,i)
    t = [0:1/Fs(i):T];
    y = cos(a*t);
    plot(t,y,'ro')
    xlabel('t (seconds)')
    ylabel('y(t)')
    title(sprintf('Fs = %.2f Hz', Fs(i)))
    axis([-5,105,-1.5])

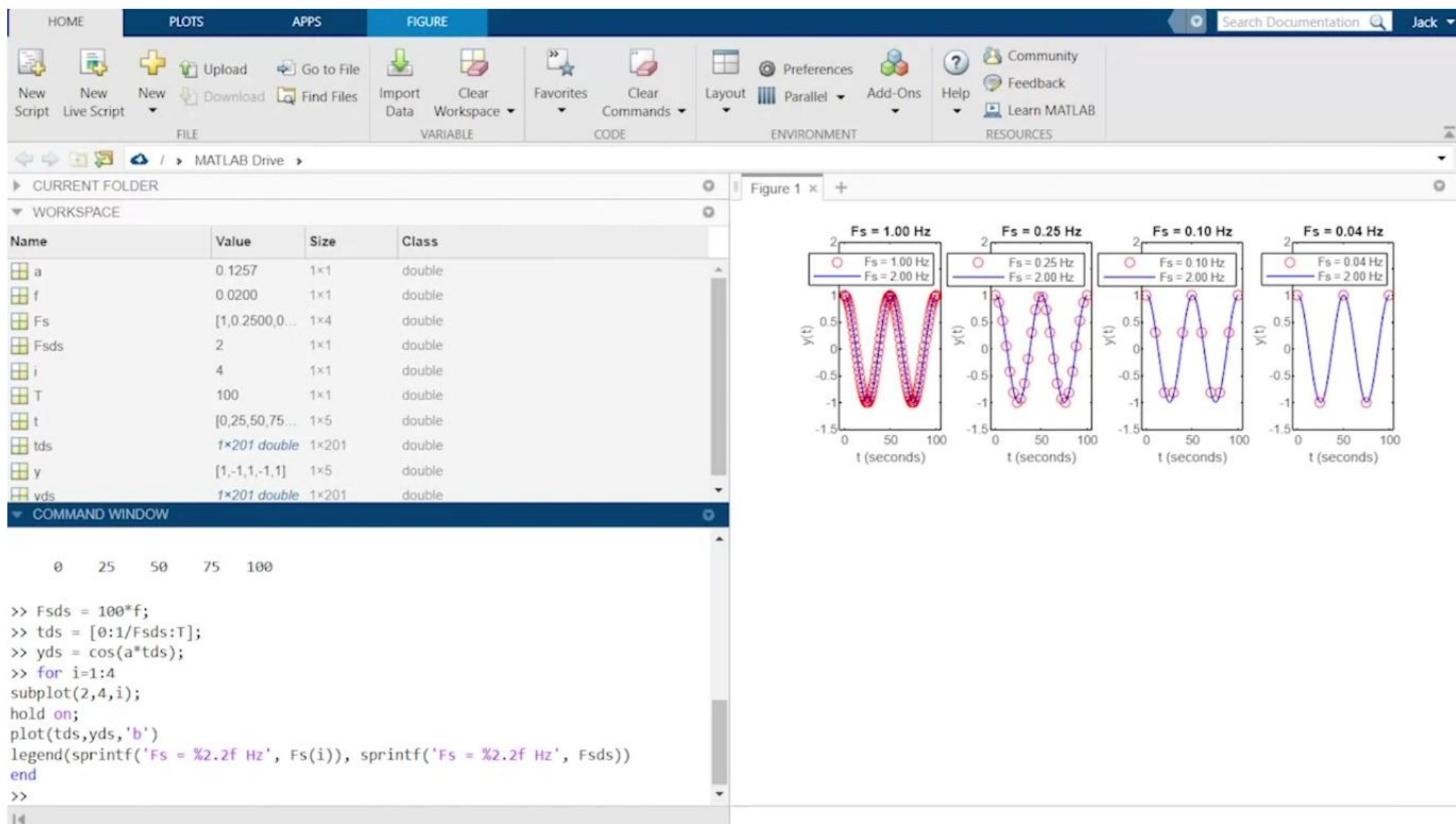
```

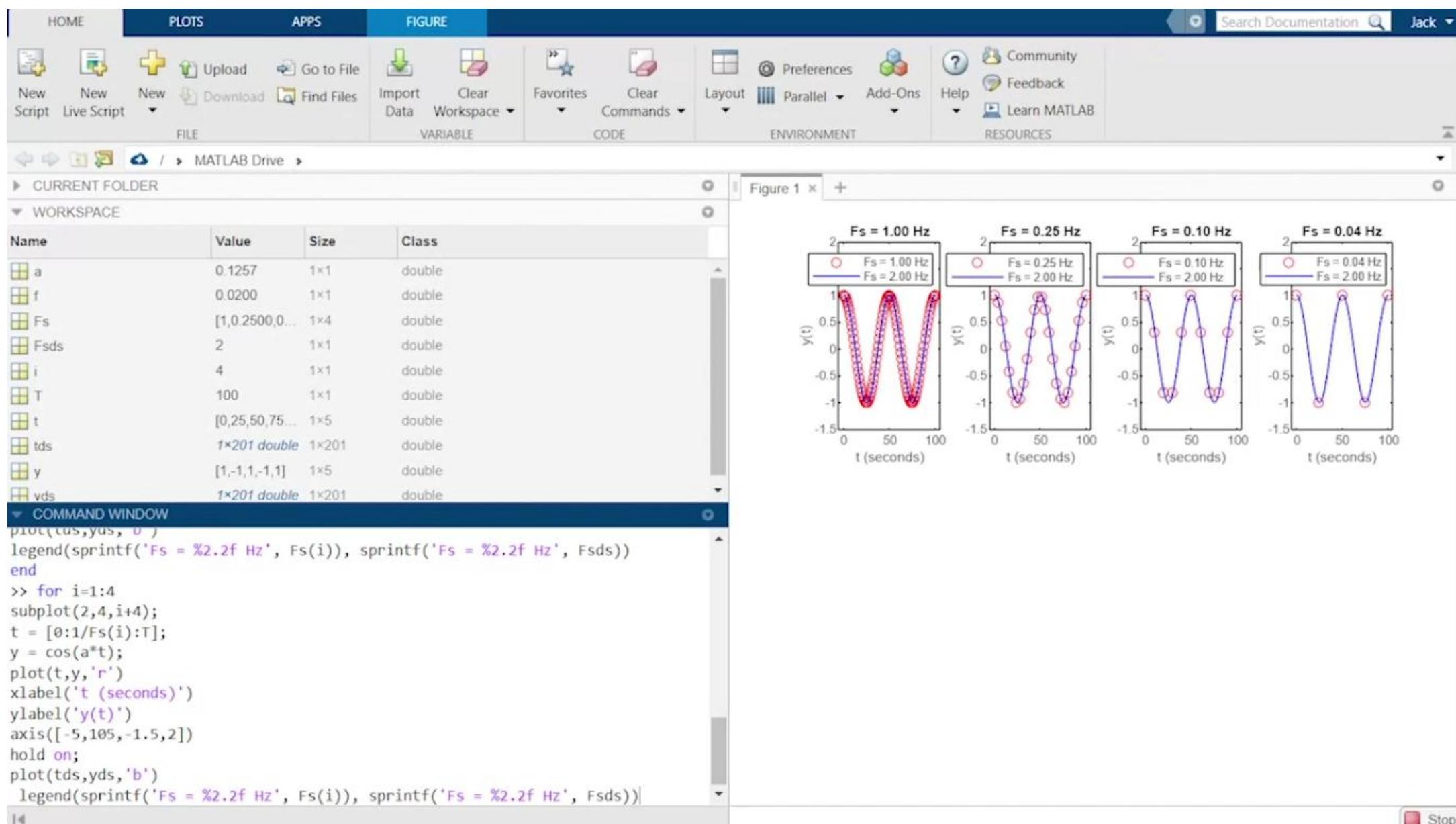
Figure 1

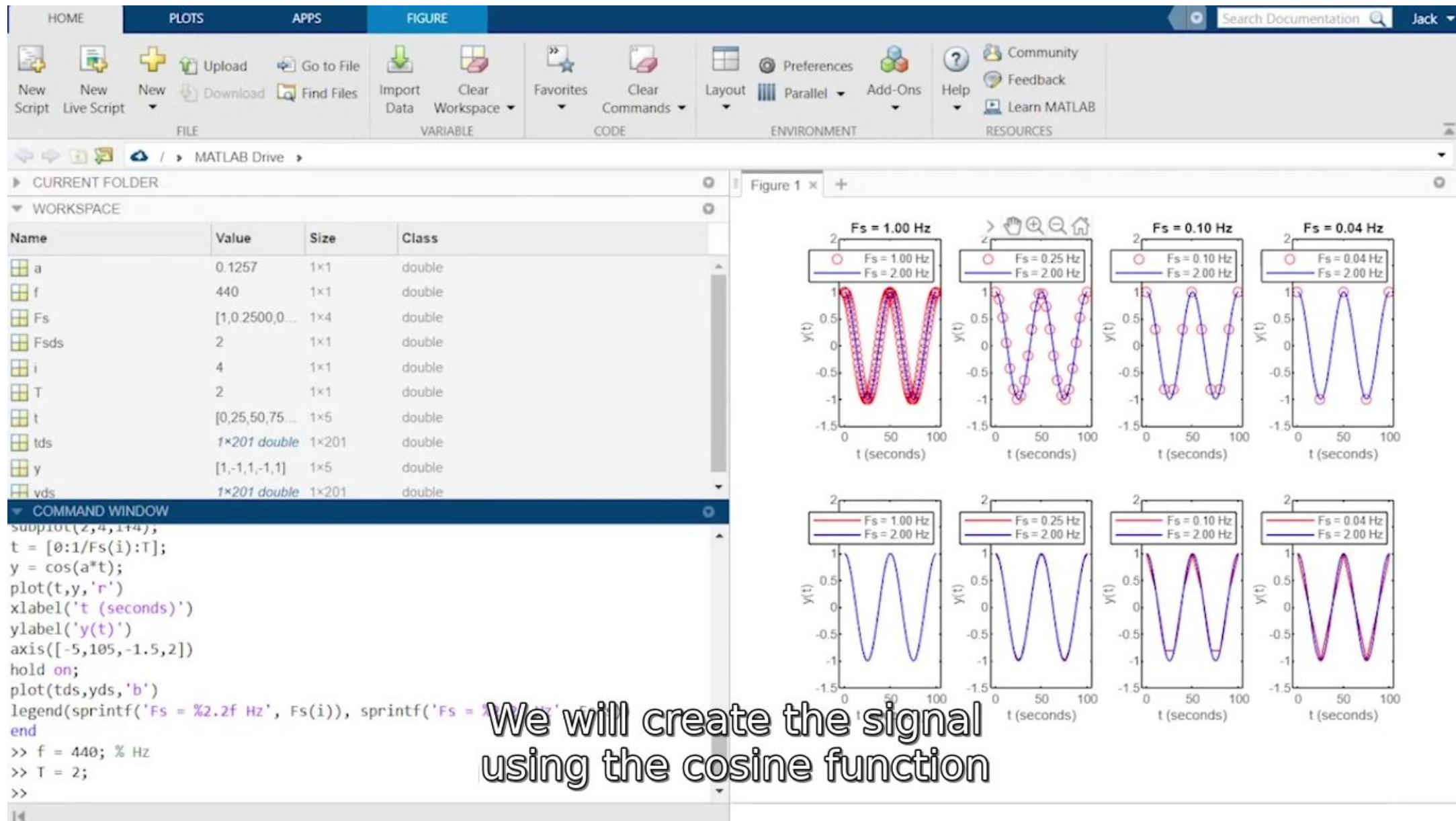
So ranging from minus 1.5 to 2,

Stop

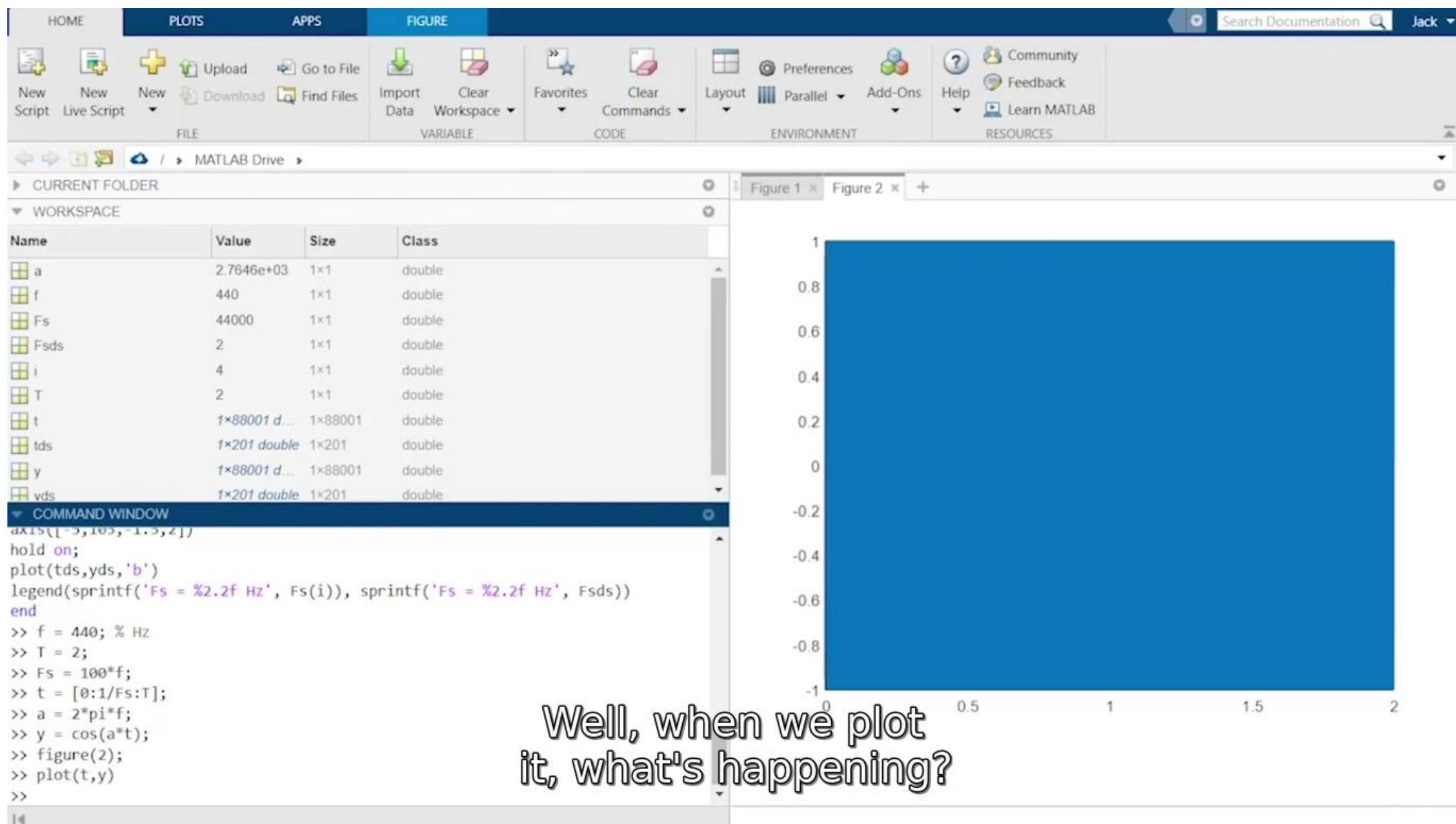


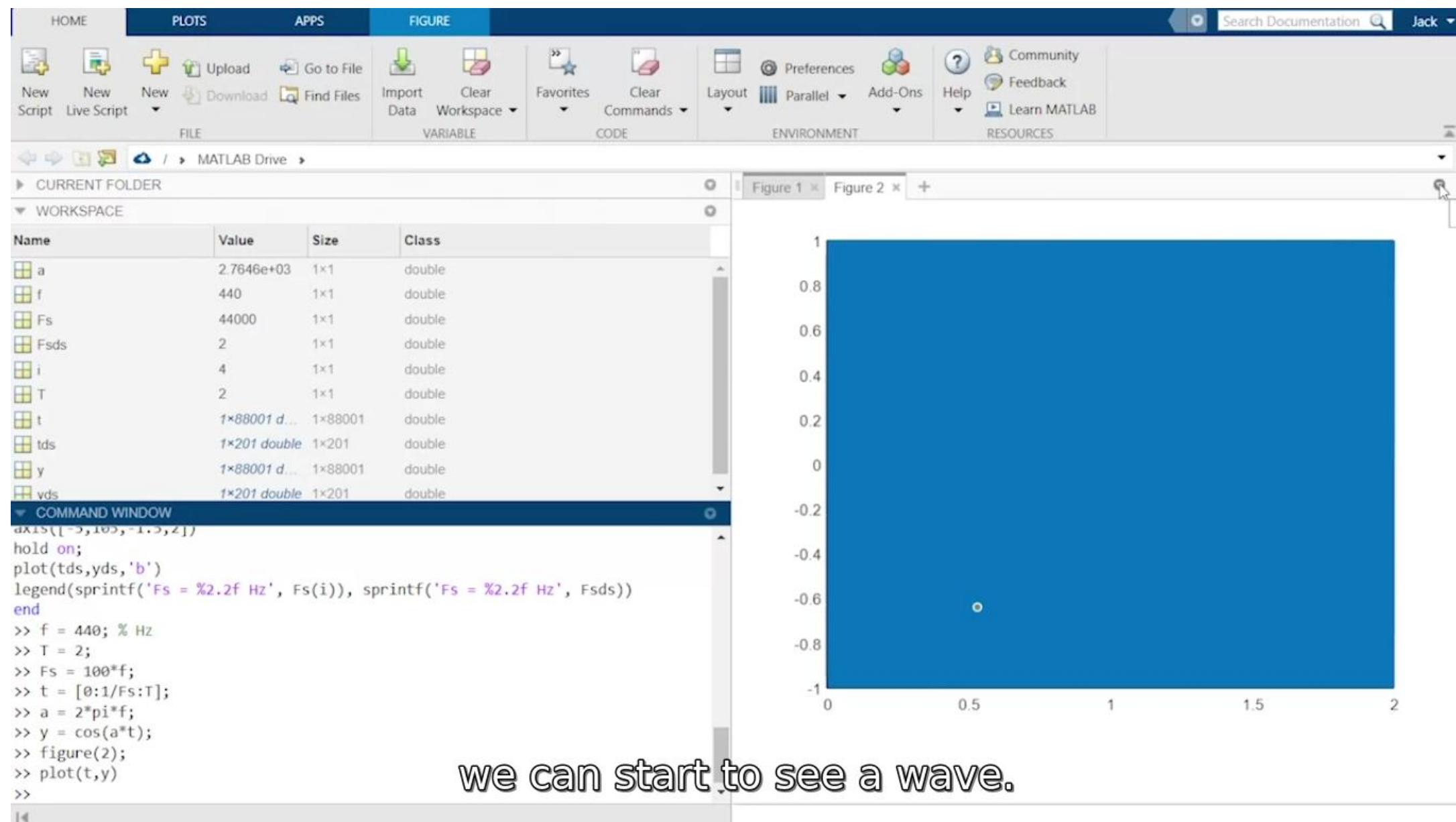


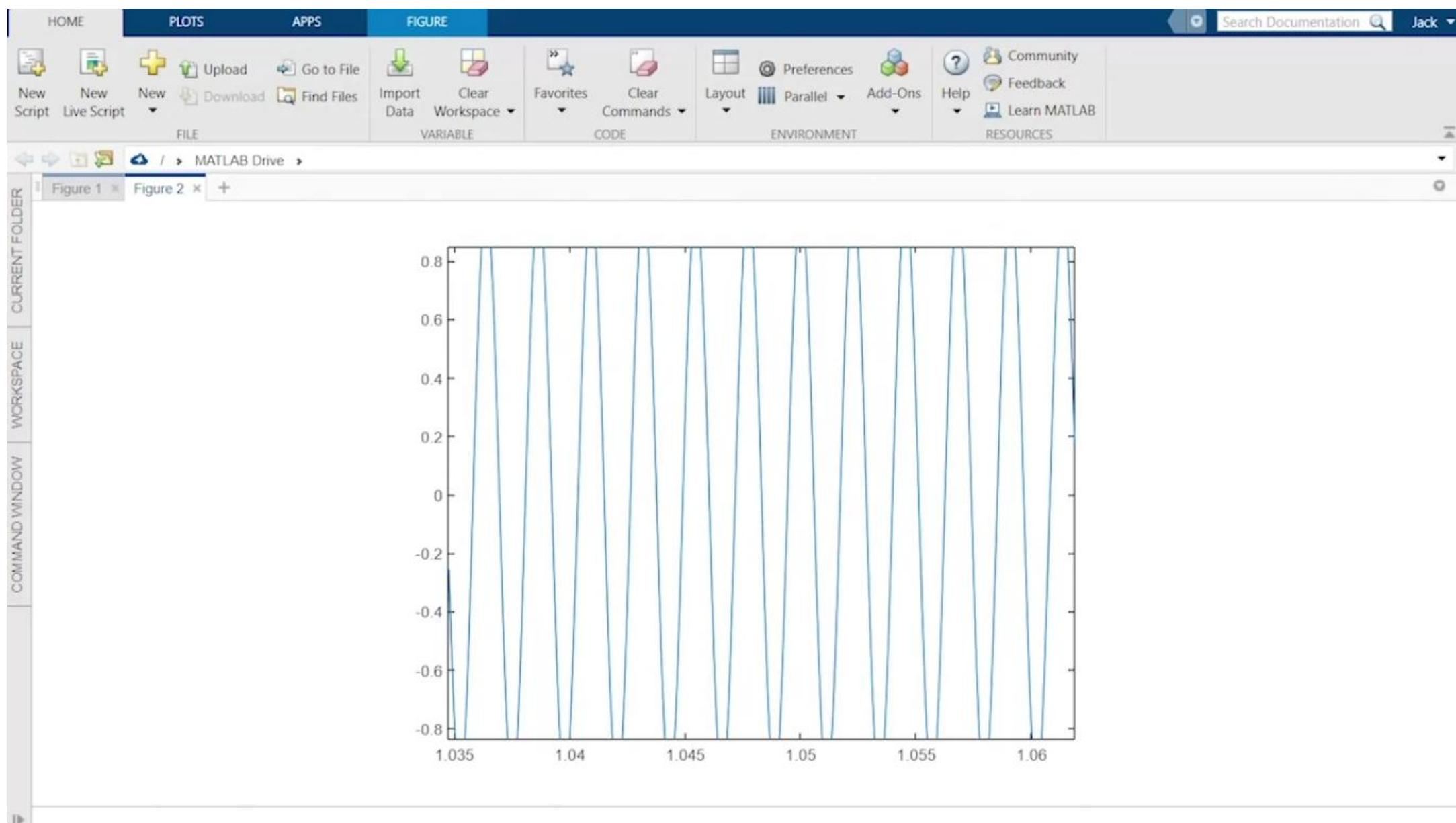


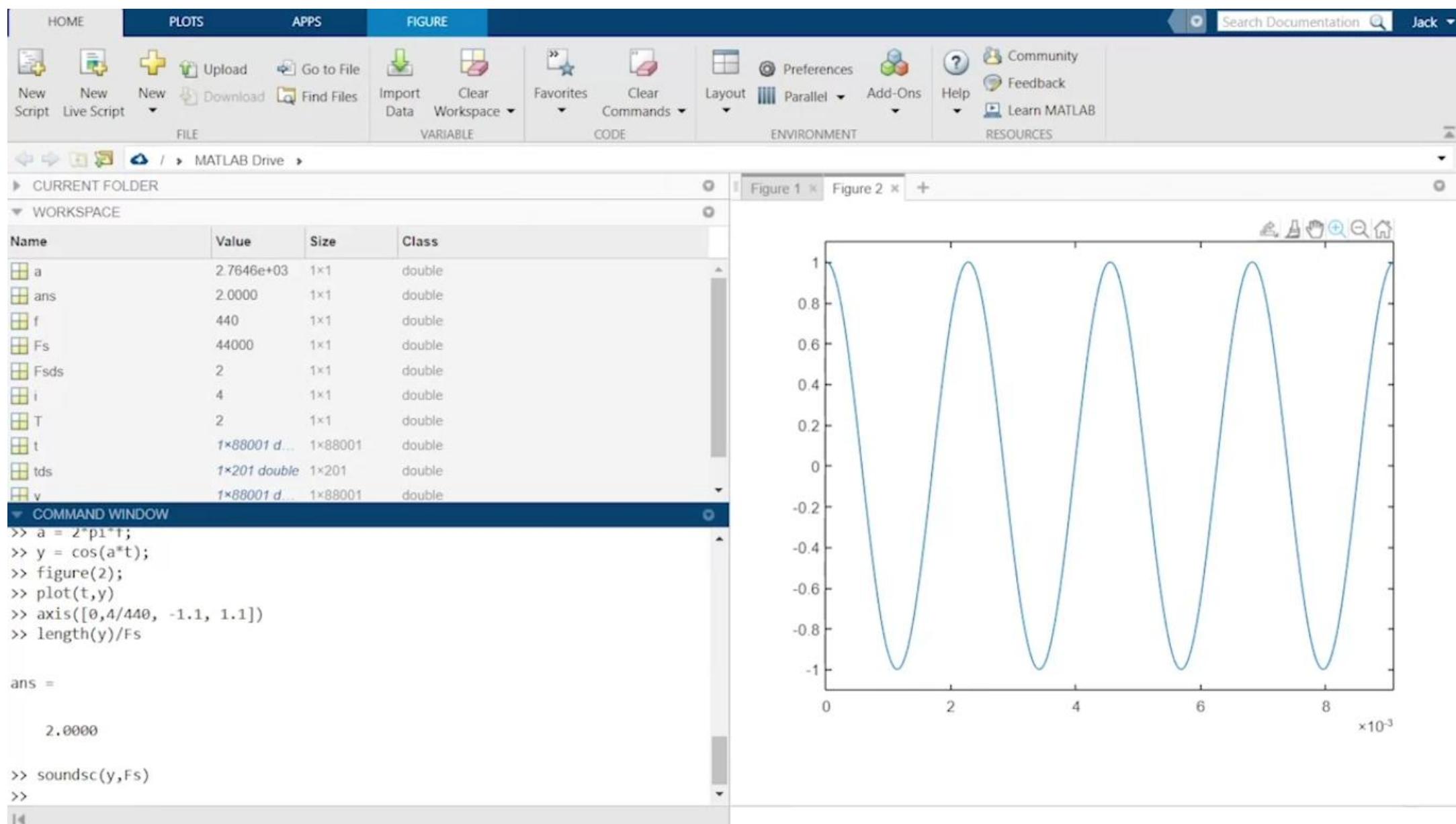


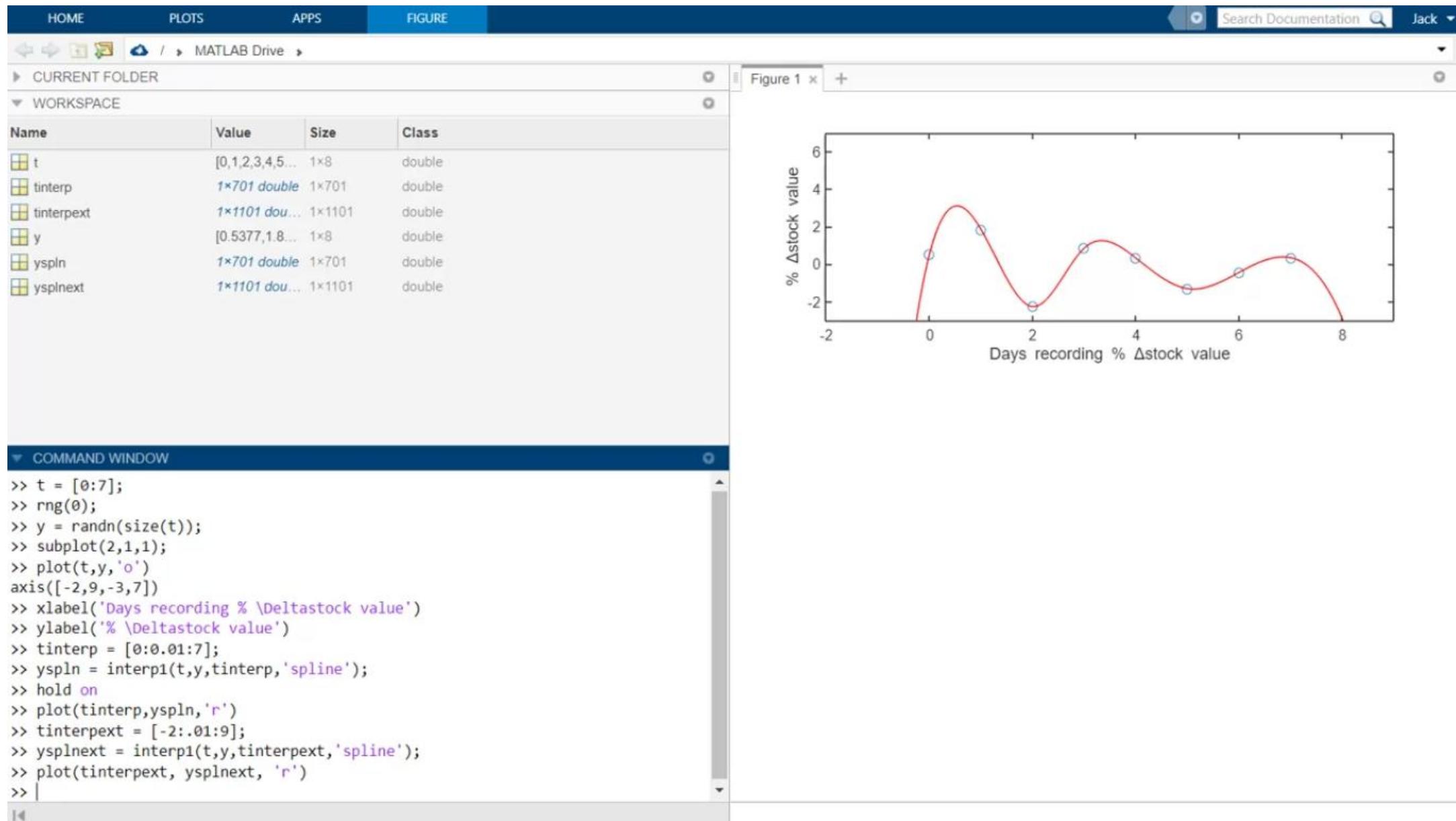
We will create the signal
using the cosine function

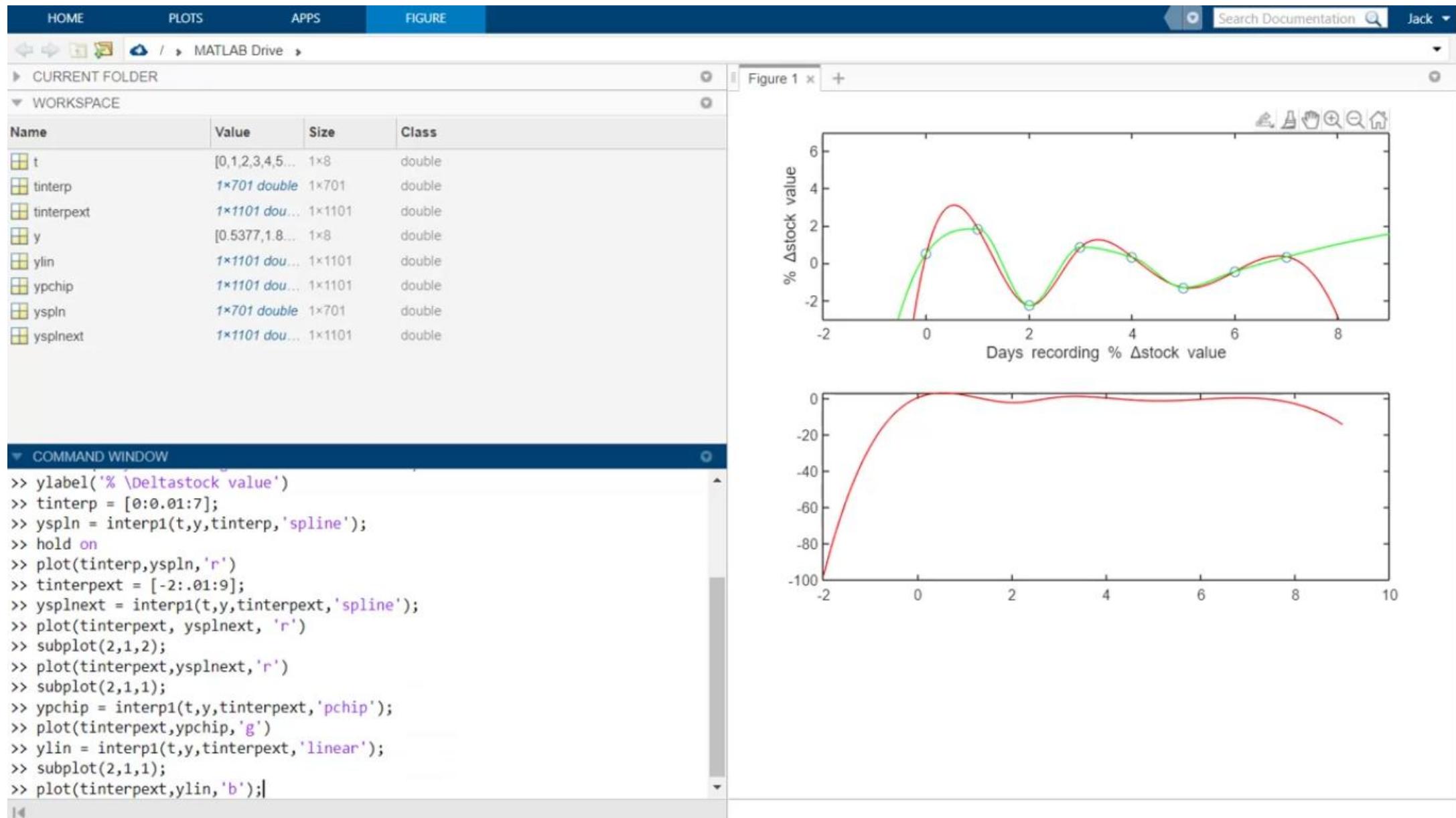


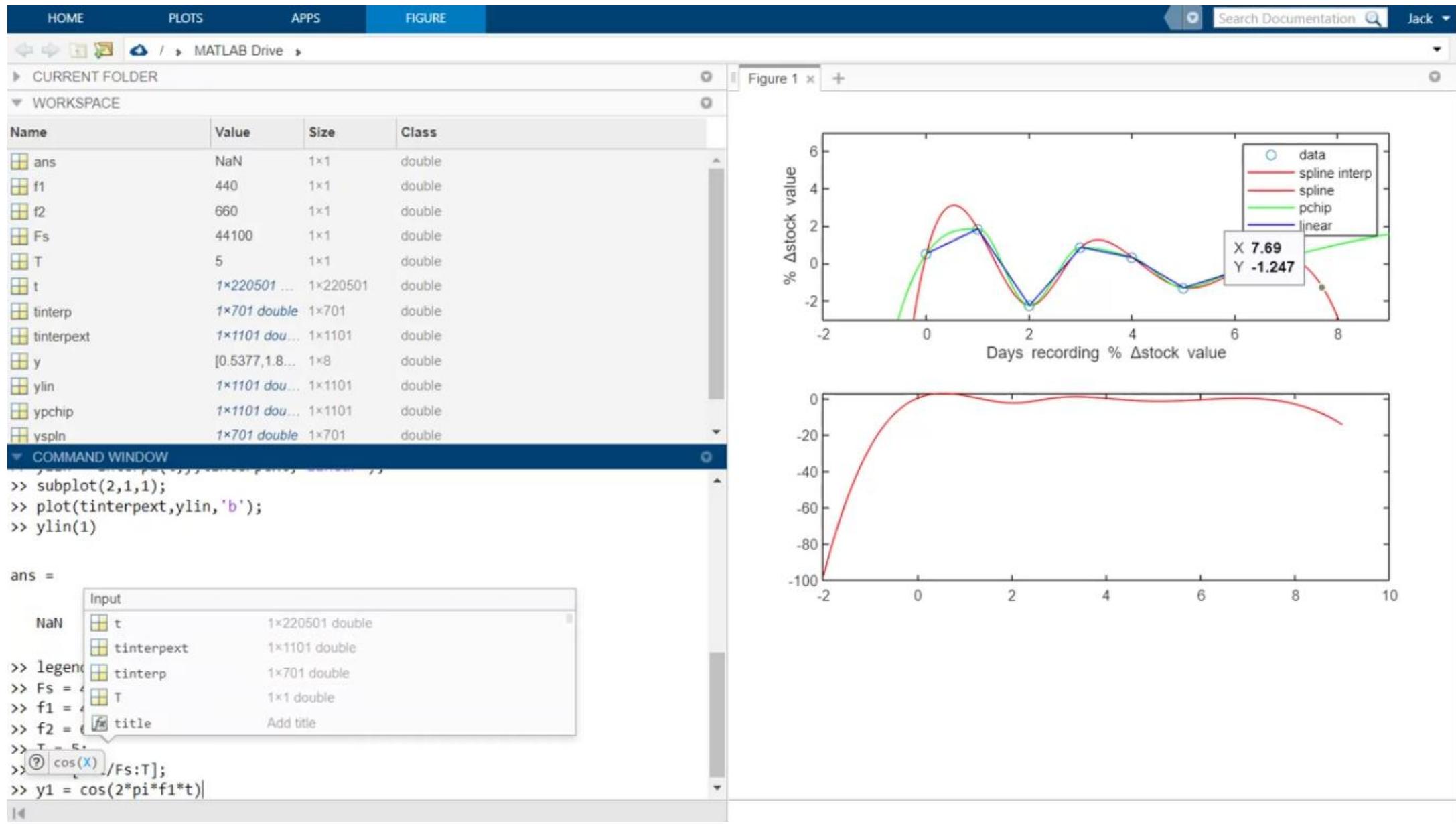


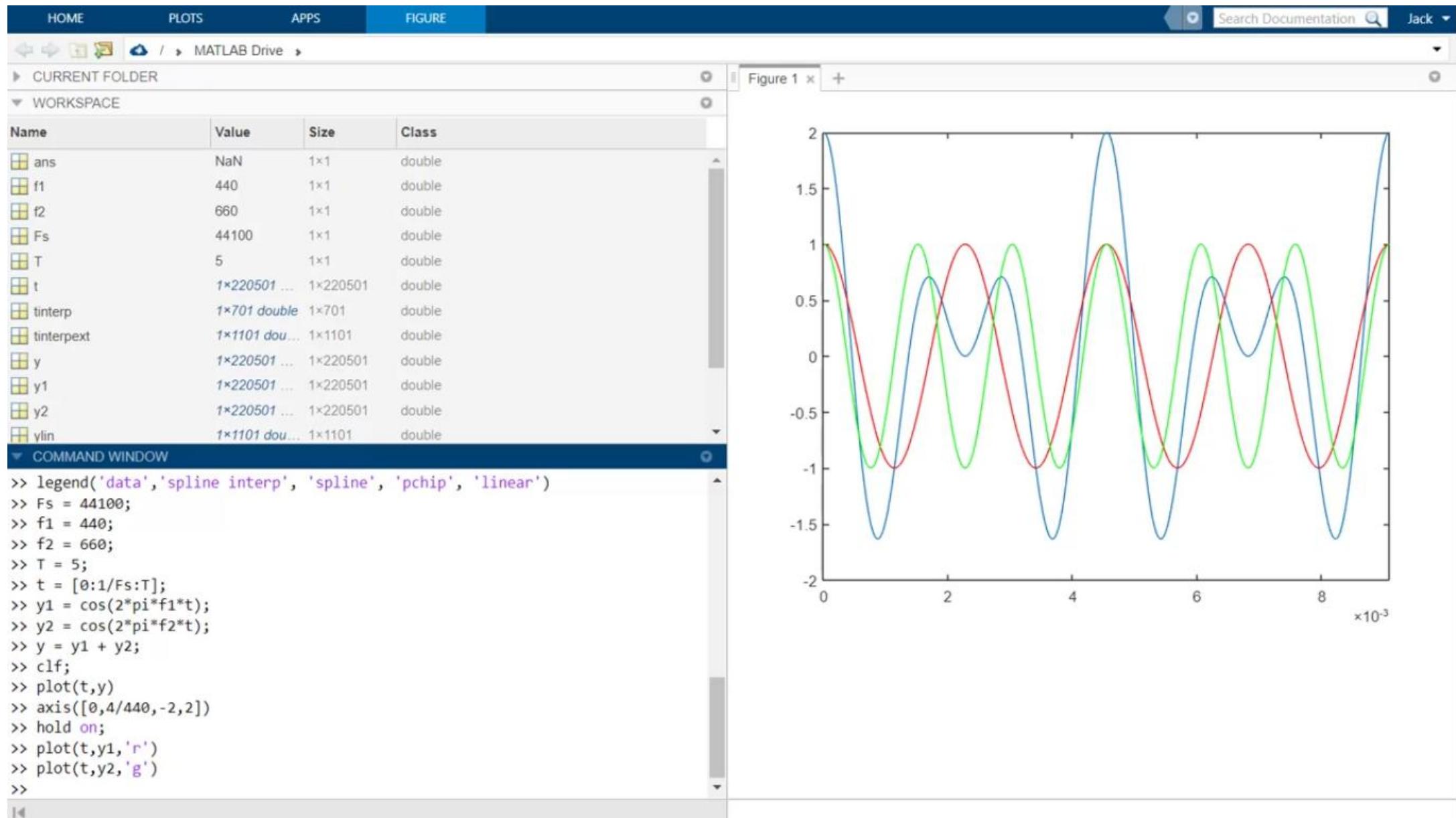


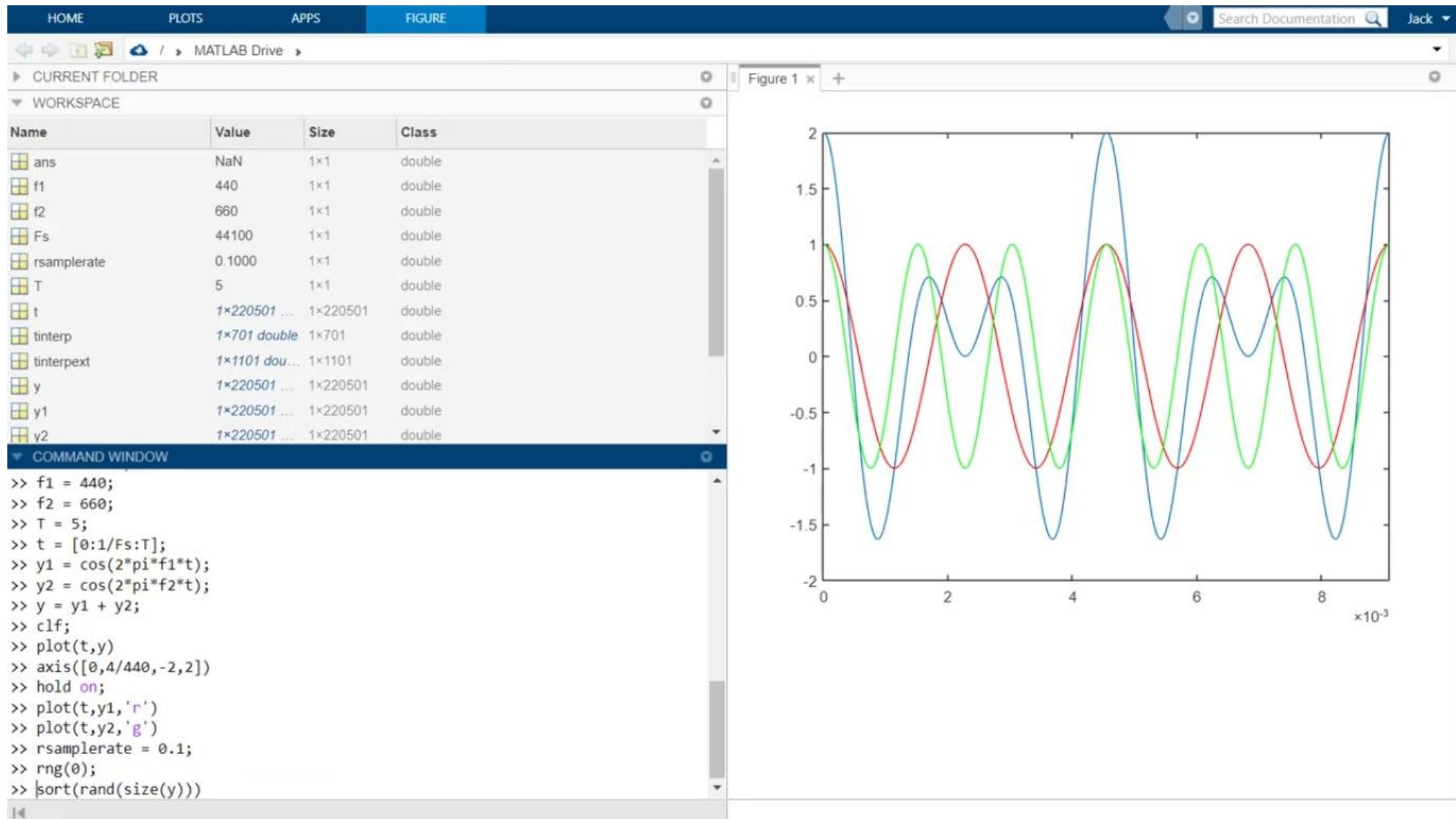


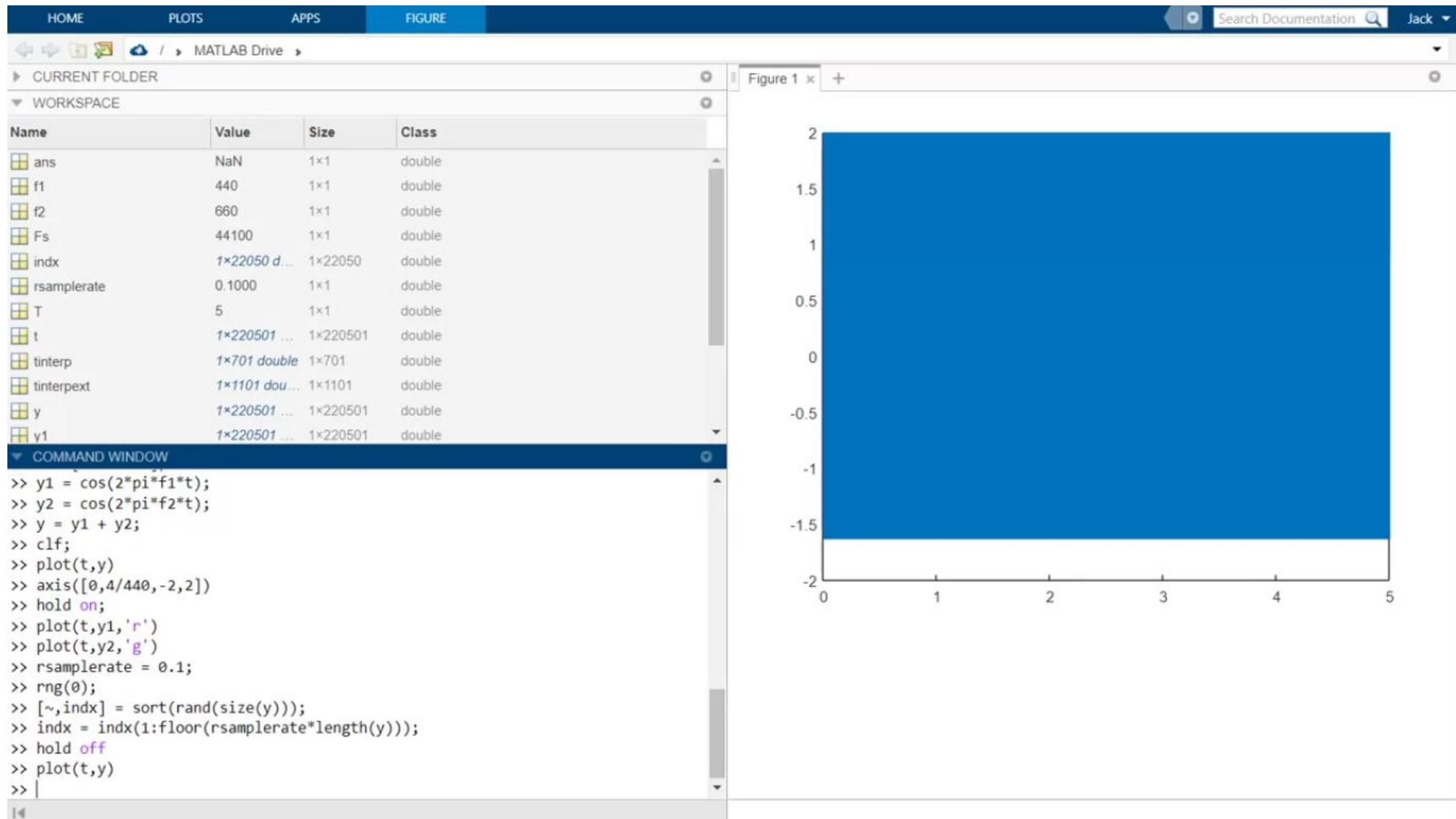


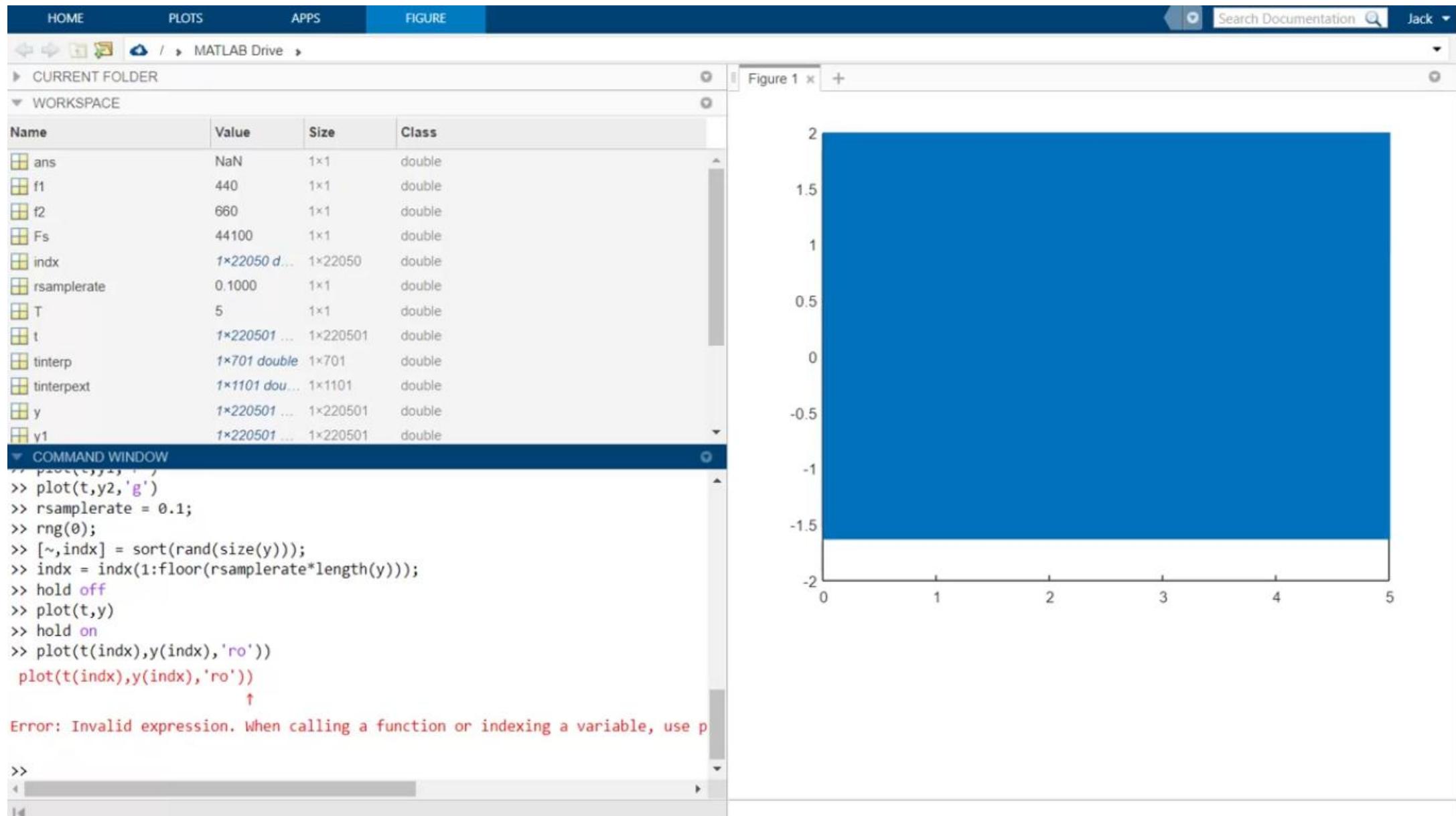


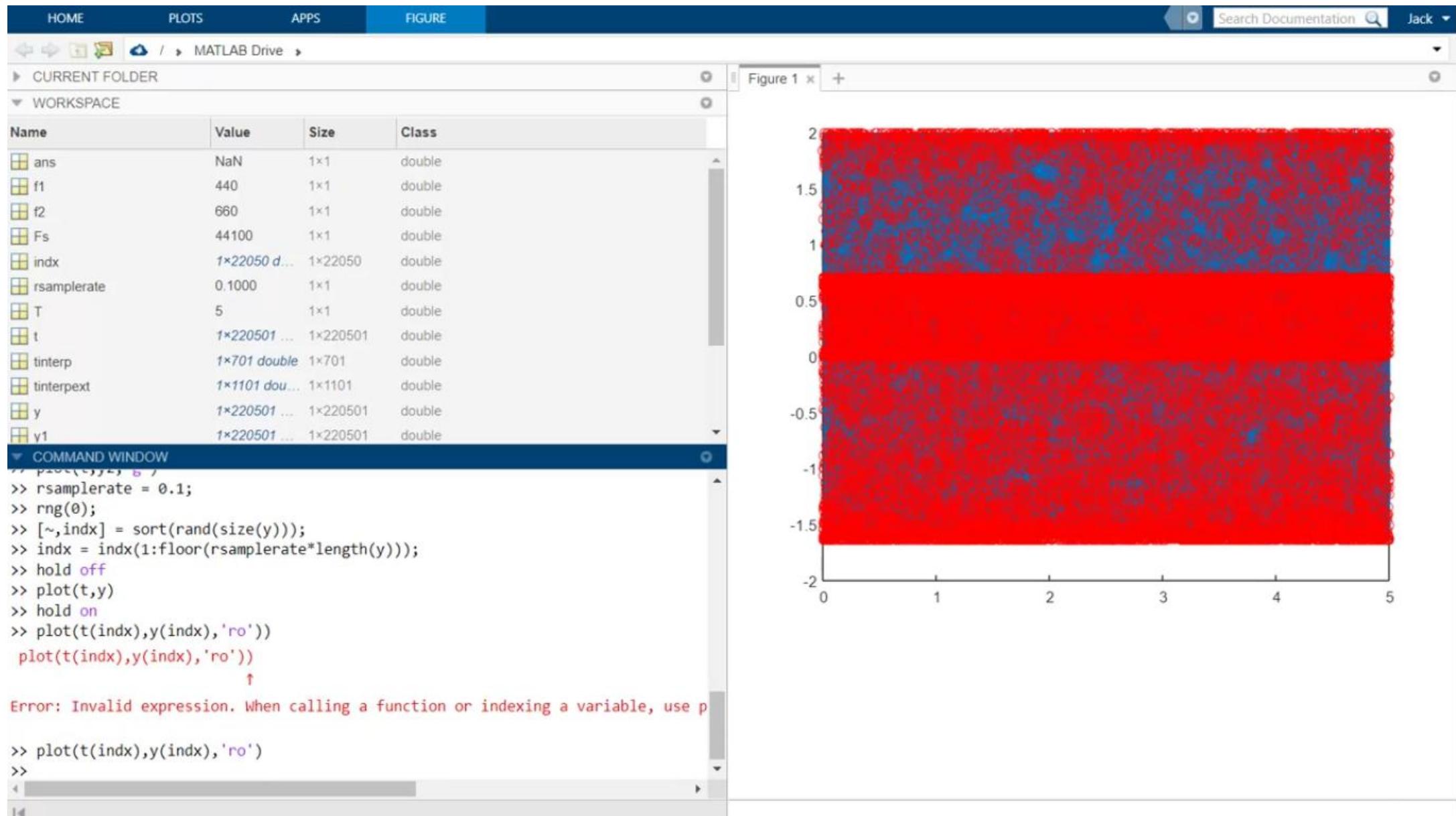


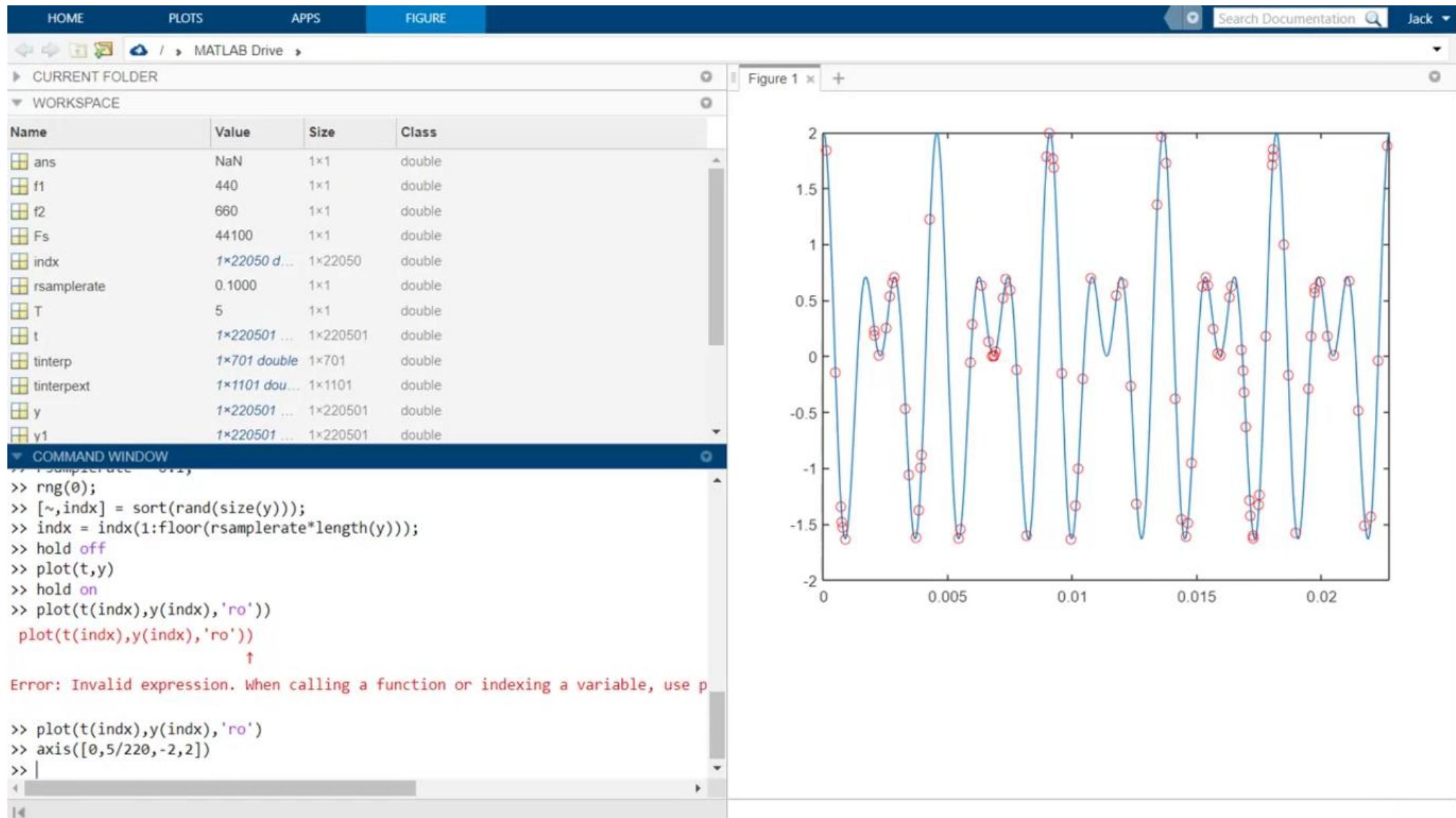


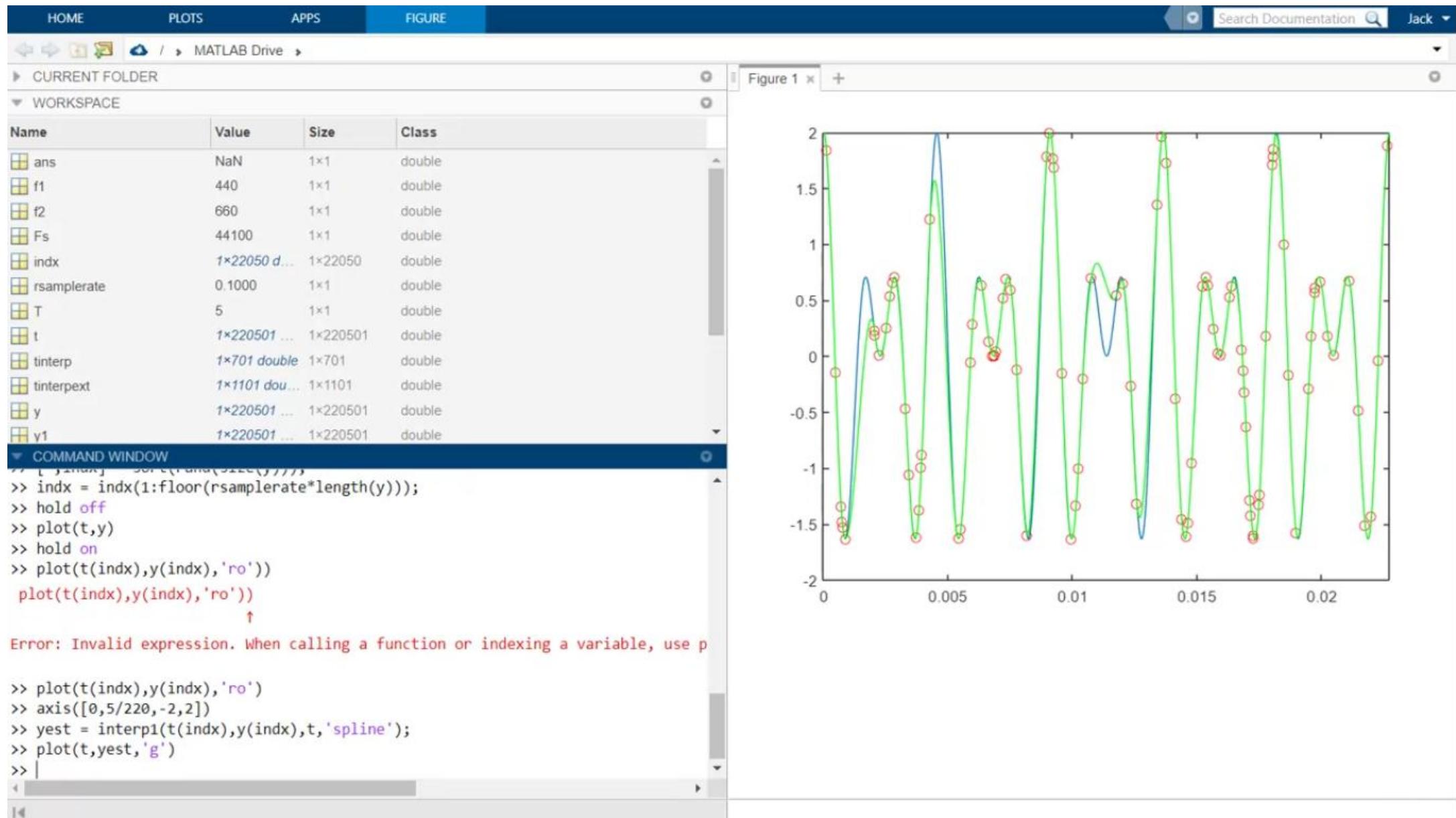


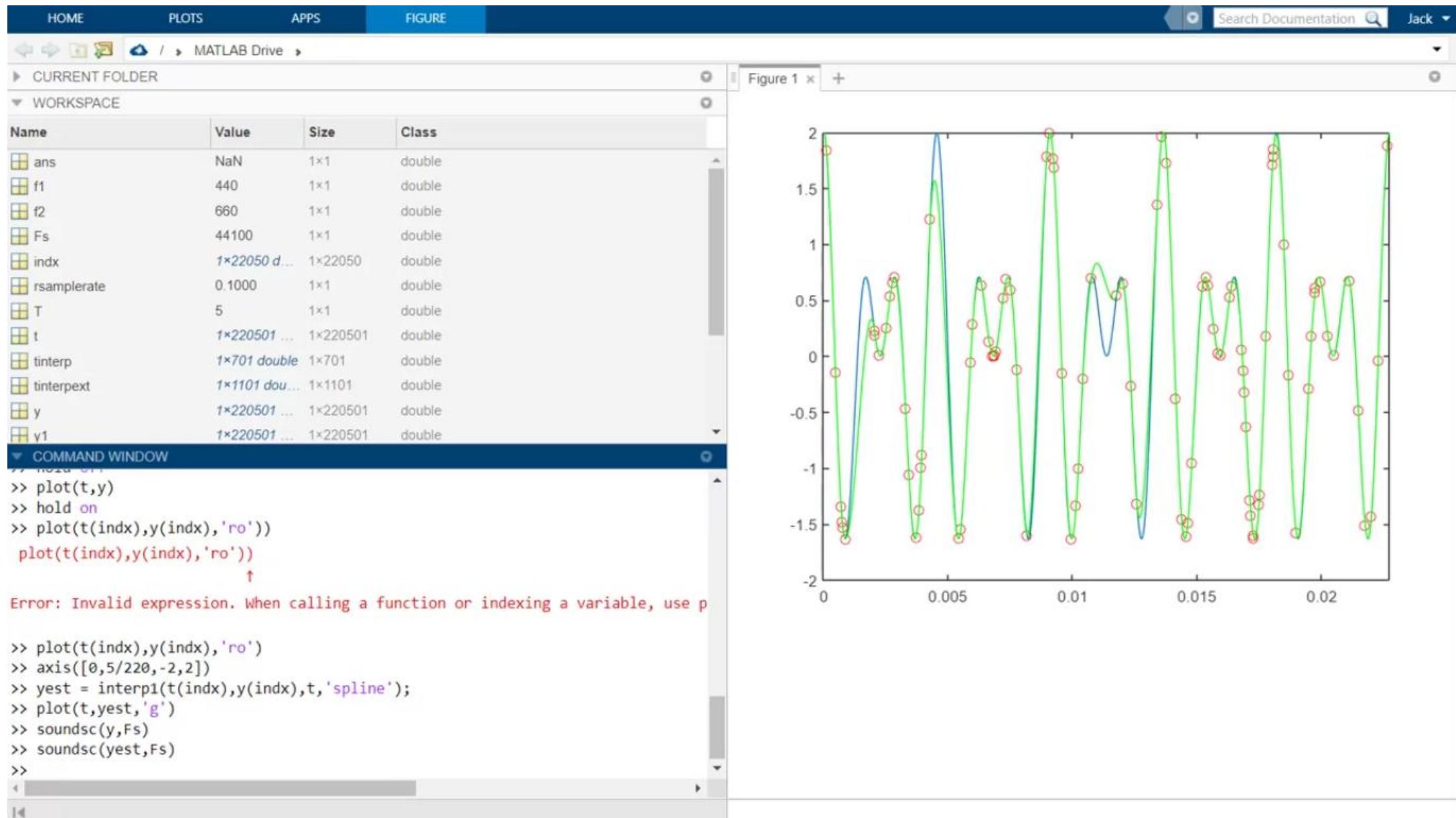


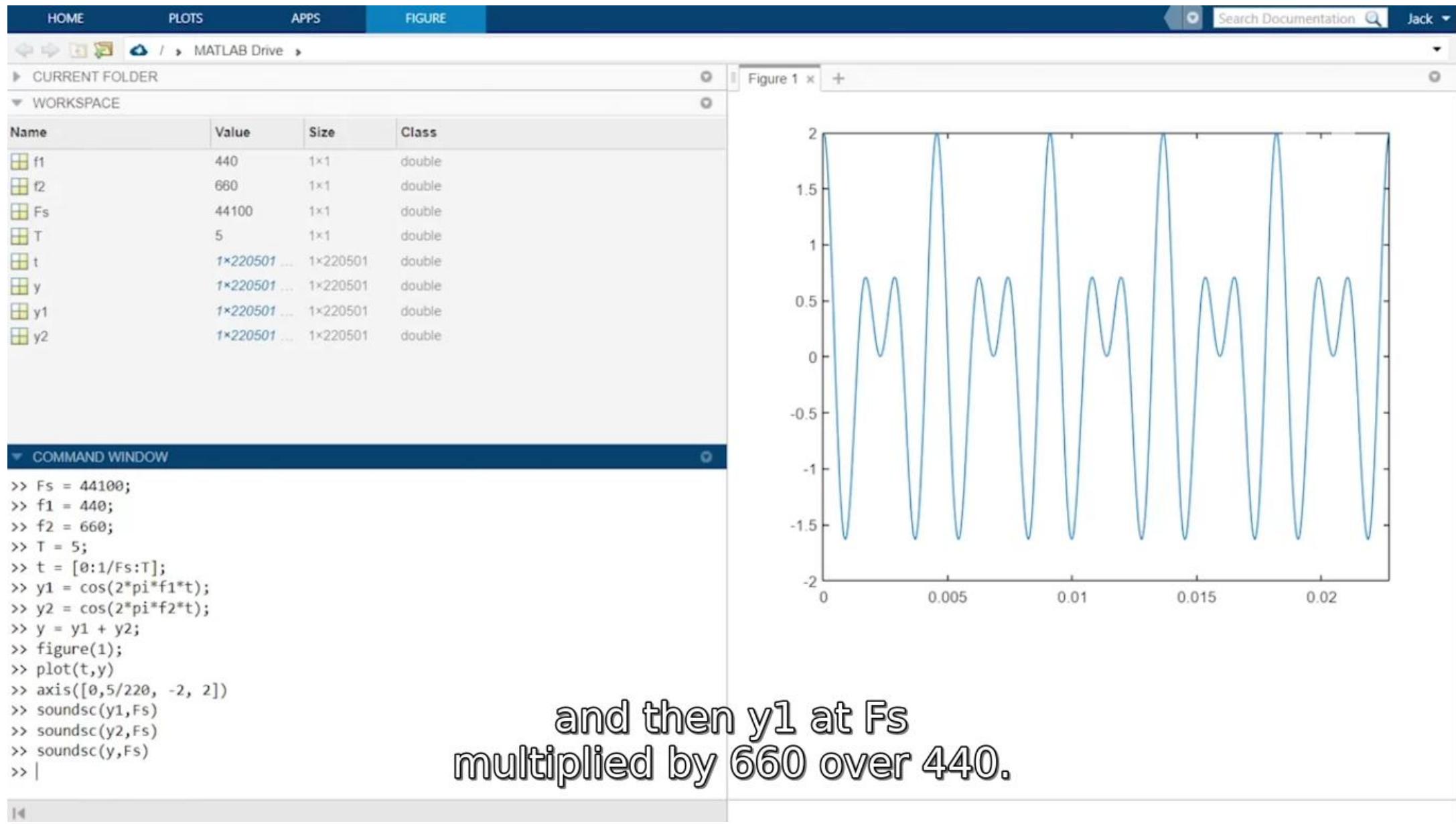












and then y1 at Fs
multiplied by 660 over 440.

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WORKSPACE

Name	Value	Size	Class
f1	440	1x1	double
f2	660	1x1	double
Fs	44100	1x1	double
fsst	96000	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
y	1x220501 ...	1x220501	double
y1	1x220501 ...	1x220501	double
y2	1x220501 ...	1x220501	double
yfd	1116288x2 ...	1116288x2	double
yst	6076484x2 ...	6076484x2	double
ystresamp	220501x2 ...	220501x2	double

COMMAND WINDOW

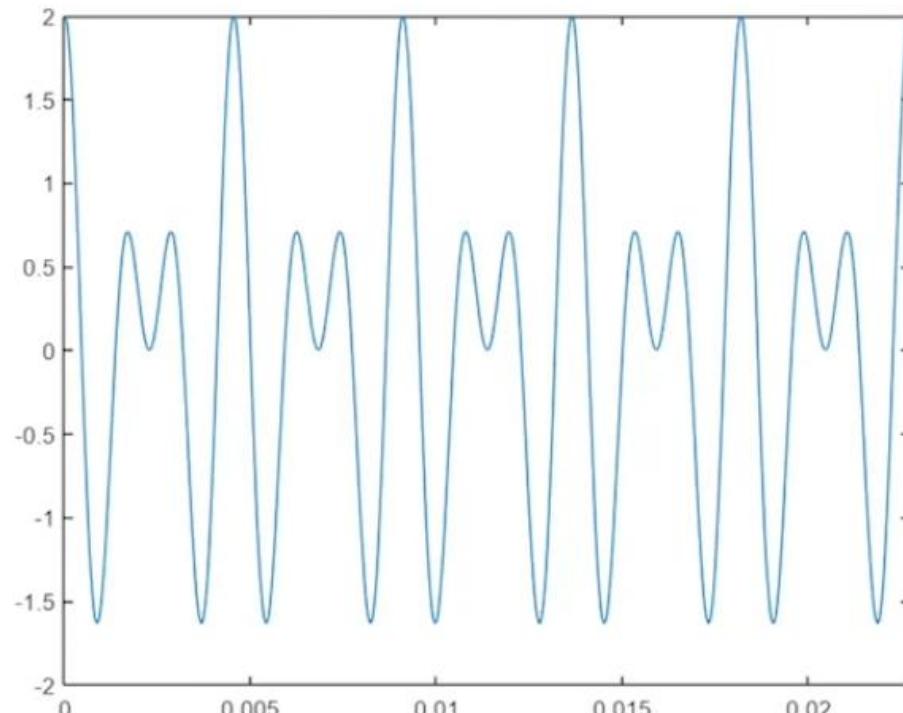
```
>> plot(t,y)
>> axis([0,5/220, -2, 2])
>> soundsc(y1,Fs)
>> soundsc(y2,Fs)
>> soundsc(y,Fs)
>> soundsc(y2,F2)
```

Unrecognized function or variable 'F2'.

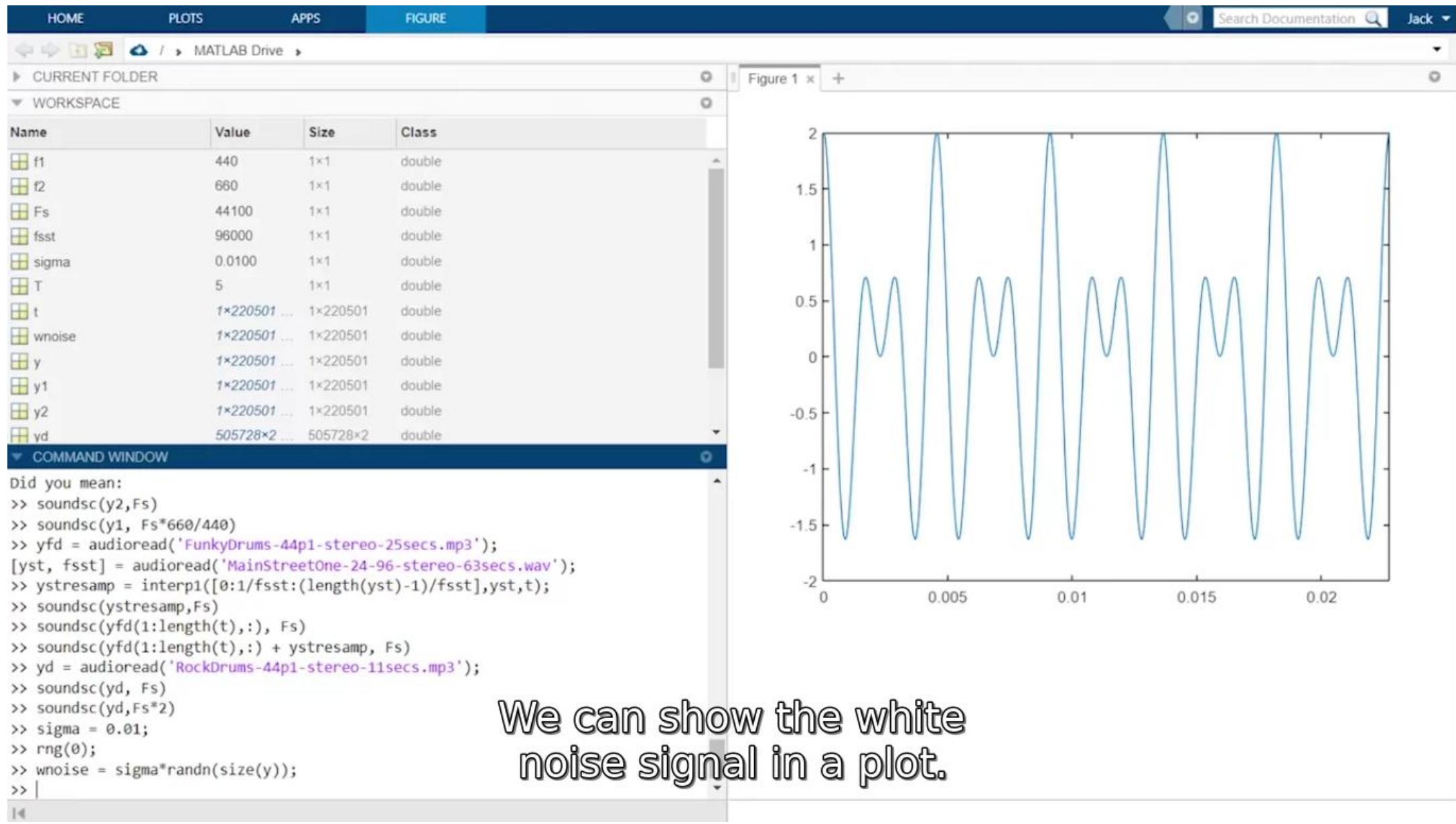
Did you mean:

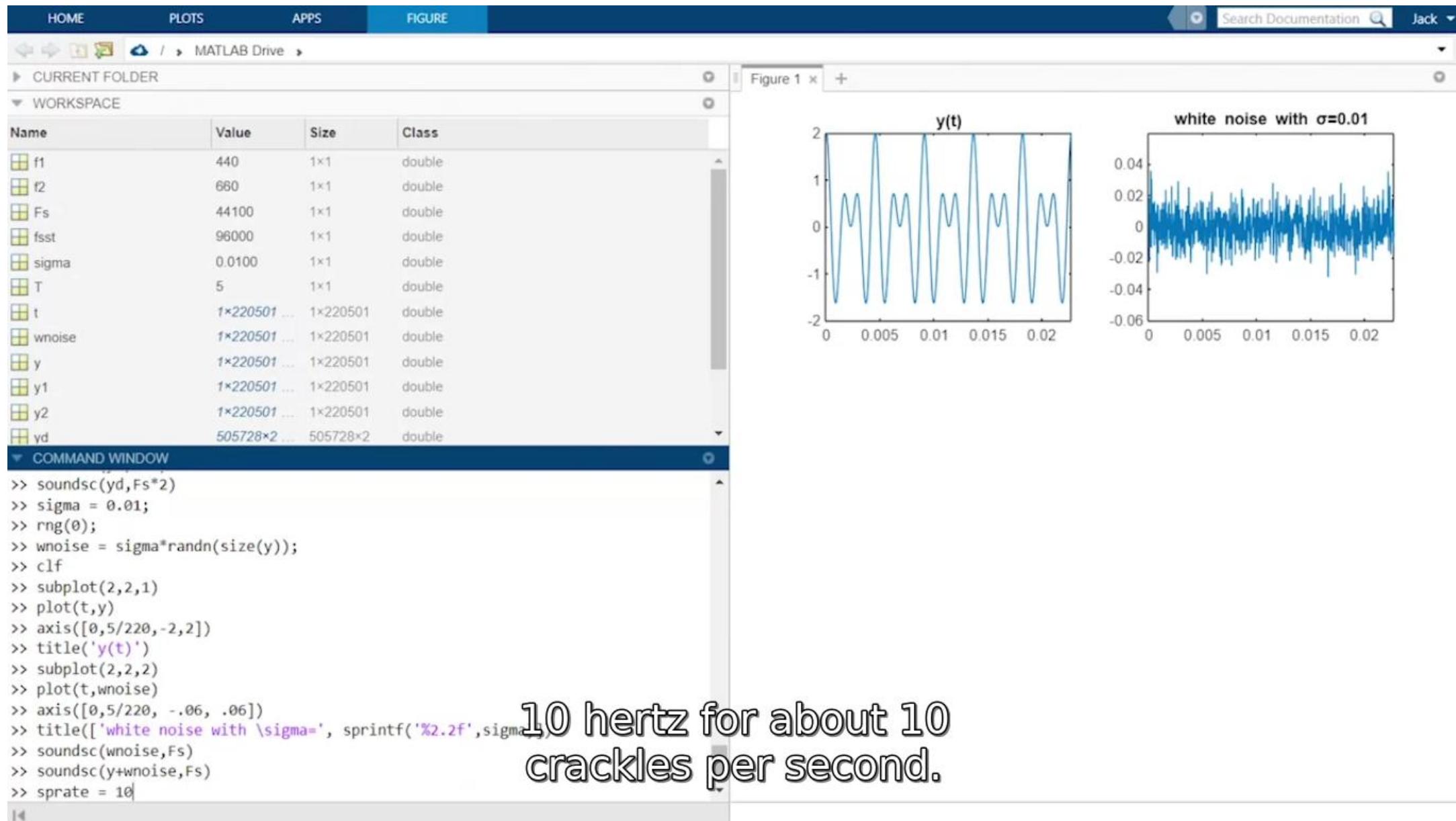
```
>> soundsc(y2,Fs)
>> soundsc(y1, Fs*660/440)
>> yfd = audioread('FunkyDrums-44p1-stereo-25secs.mp3');
>> [yst, fsst] = audioread('MainStreetOne-24-96-stereo-63secs.wav');
>> ystresamp = interp1([0:1/fsst:(length(yst)-1)/fsst],yst,t);
>> soundsc(ystresamp,Fs)
```

Figure 1 x +



Busy





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WORKSPACE

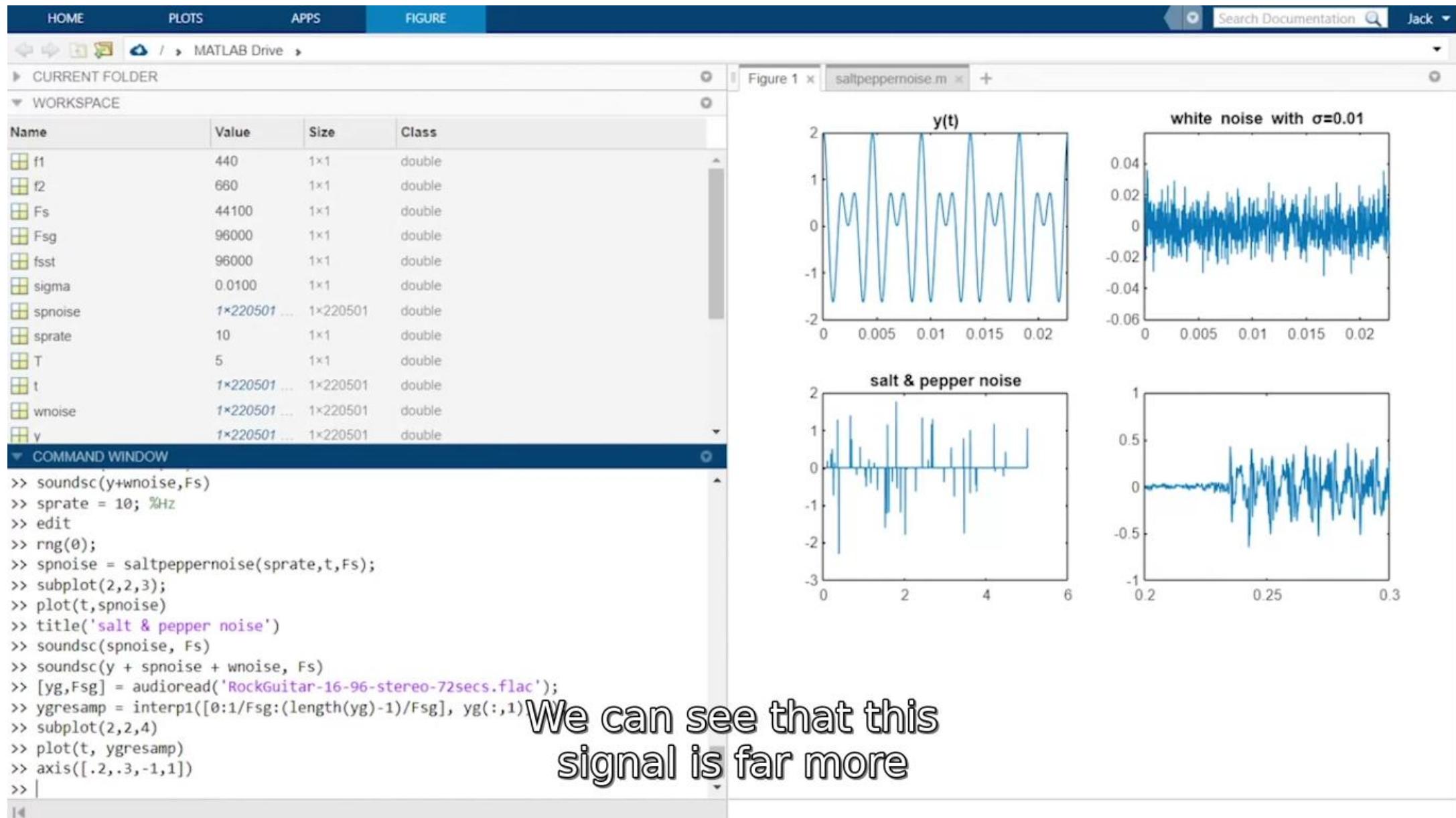
Name	Value	Size	Class
f1	440	1x1	double
f2	680	1x1	double
Fs	44100	1x1	double
fsst	96000	1x1	double
sigma	0.0100	1x1	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
wnoise	1x220501 ...	1x220501	double
y	1x220501 ...	1x220501	double
y1	1x220501 ...	1x220501	double
y2	1x220501 ...	1x220501	double

COMMAND WINDOW

```
>> wnoise = sigma*randn(size(y));
>> clf
>> subplot(2,2,1)
>> plot(t,y)
>> axis([0,5/220,-2,2])
>> title('y(t)')
>> subplot(2,2,2)
>> plot(t,wnoise)
>> axis([0,5/220, -.06, .06])
>> title(['white noise with \sigma=' , sprintf('%2.2f',sigma)])
>> soundsc(wnoise,Fs)
>> soundsc(y+wnoise,Fs)
>> sprate = 10; %Hz
>> edit
>> rng(0);
>> spnoise = saltpeppernoise(sprate,t,Fs);
```

Figure 1 x saltpeppernoise.m x +

```
function spnoise = saltpeppernoise(sprate, t, Fs)
    spnoise = zeros(size(t));
    [~,indx] = sort(rand(size(t)));
    indx = indx(1:floor(sprate/Fs*length(t)));
    spnoise(indx) = randn(size(indx));
end
```



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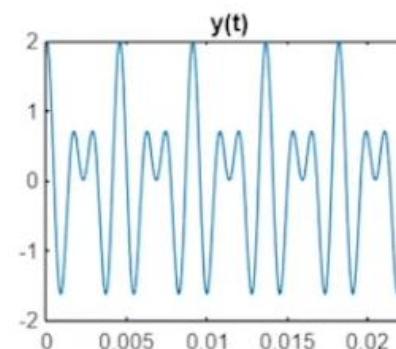
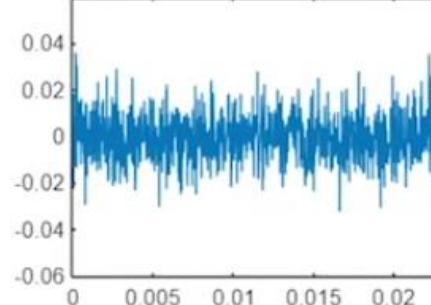
WORKSPACE

Name	Value	Size	Class
clp	0.0918	1x1	double
f1	440	1x1	double
f2	660	1x1	double
Fs	44100	1x1	double
Fsg	96000	1x1	double
fsst	96000	1x1	double
mx	0.9178	1x1	double
sigma	0.0100	1x1	double
spnoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double

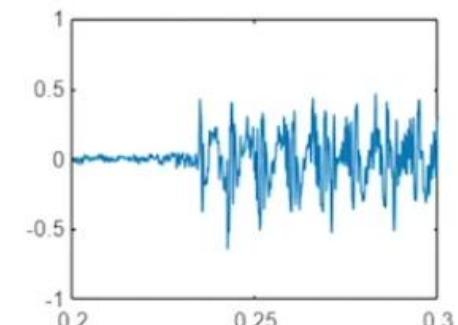
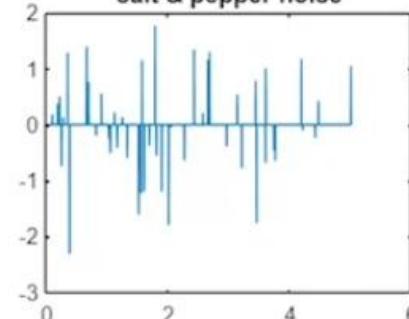
COMMAND WINDOW

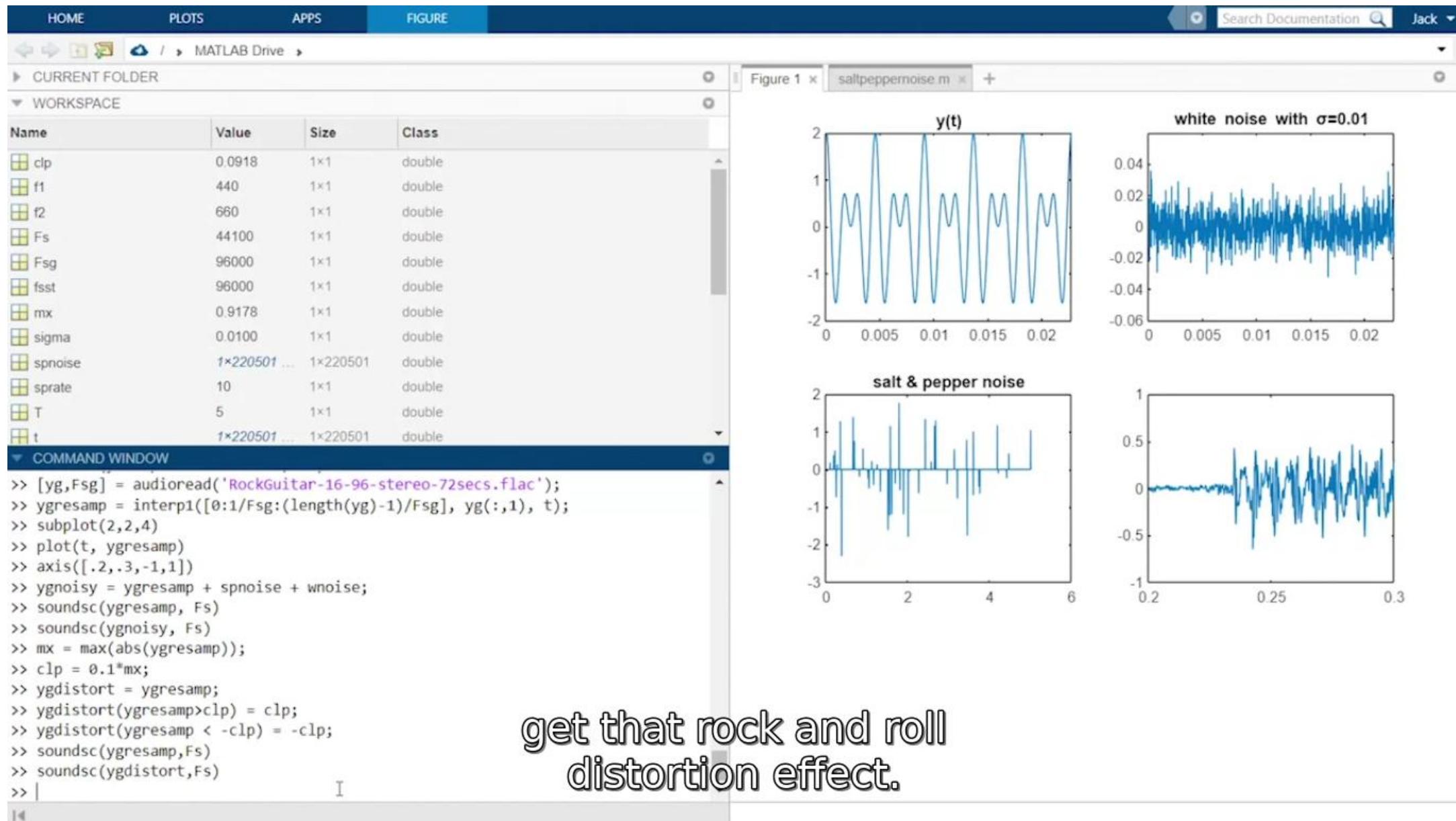
```
>> soundsc(y + spnoise + wnoise, Fs)
>> [yg,Fsg] = audioread('RockGuitar-16-96-stereo-72secs.flac');
>> ygresamp = interp1([0:1/Fsg:(length(yg)-1)/Fsg], yg(:,1), t);
>> subplot(2,2,4)
>> plot(t, ygresamp)
>> axis([.2,.3,-1,1])
>> ygnoisy = ygresamp + spnoise + wnoise;
>> soundsc(ygnoisy, Fs)
>> soundsc(ygnoisy, Fs)
>> mx = max(abs(ygnoisy));
>> clp = 0.1*mx;
>> ygdistort = ygnoisy;
>> ygdistort(ygnoisy>clp) = clp;
>> ygdistort(ygnoisy < -clp) = -clp;
>> soundsc(ygdistort,Fs)
>> |
```

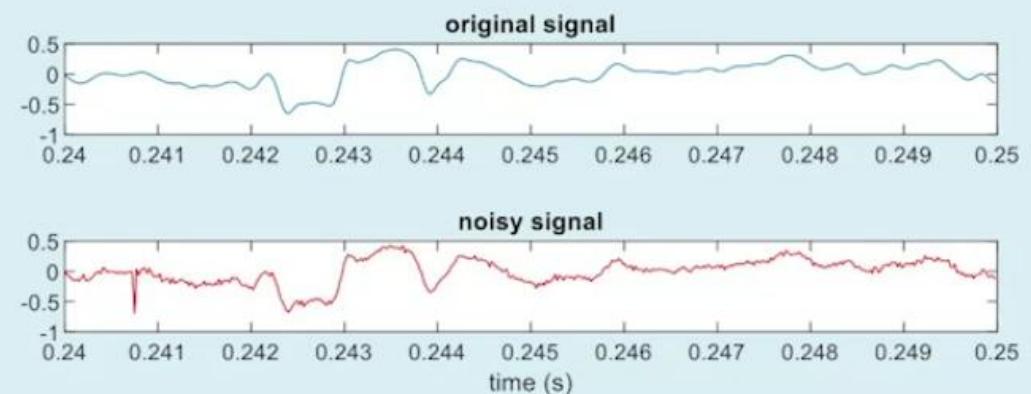
Figure 1 x saltpeppernoise.m +

white noise with $\sigma=0.01$ 

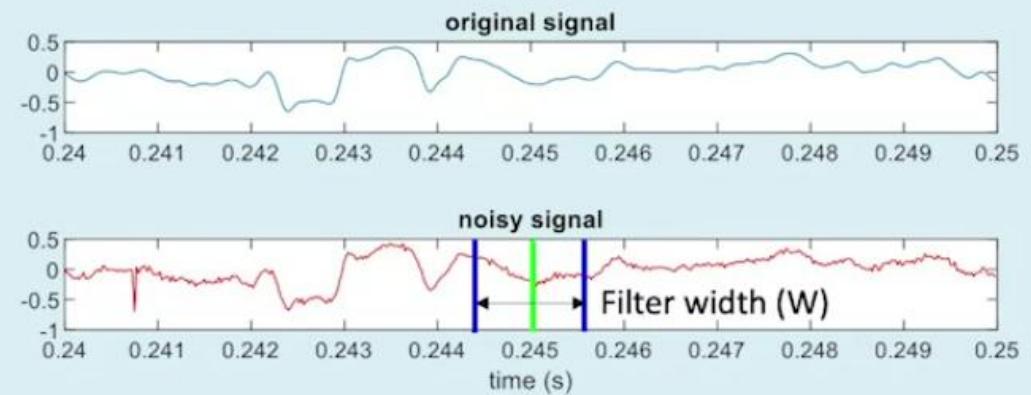
salt & pepper noise



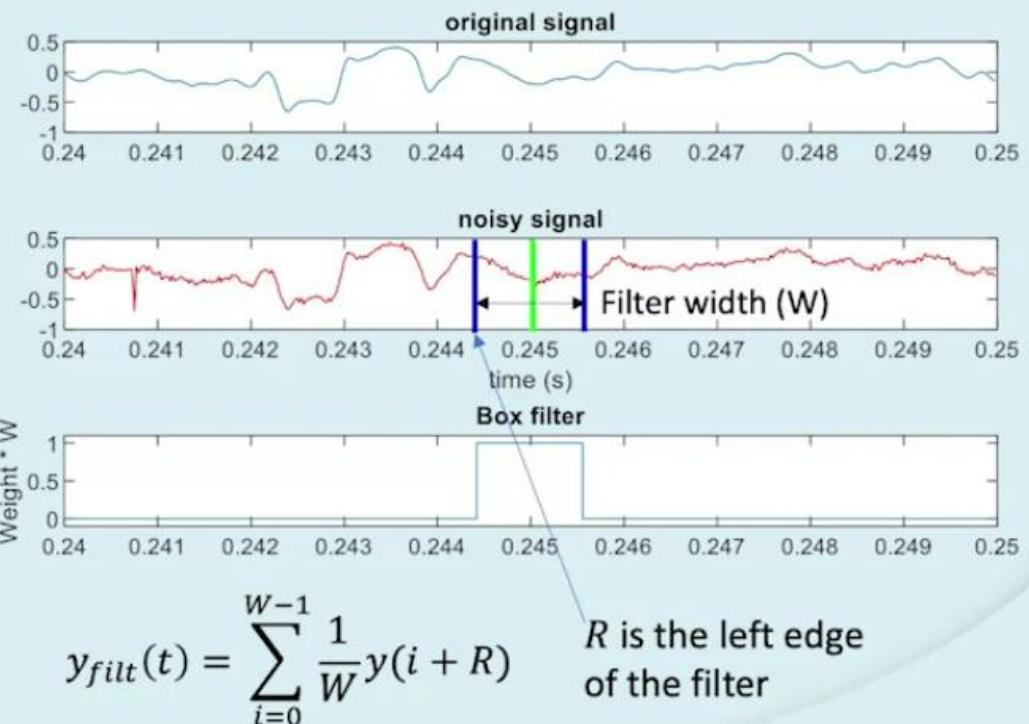


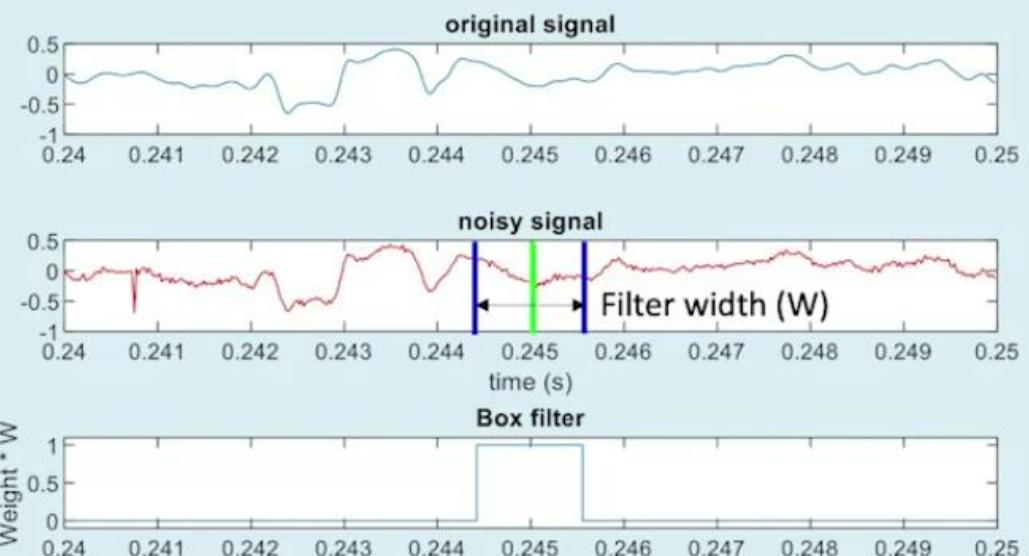


has mostly high
frequency content.

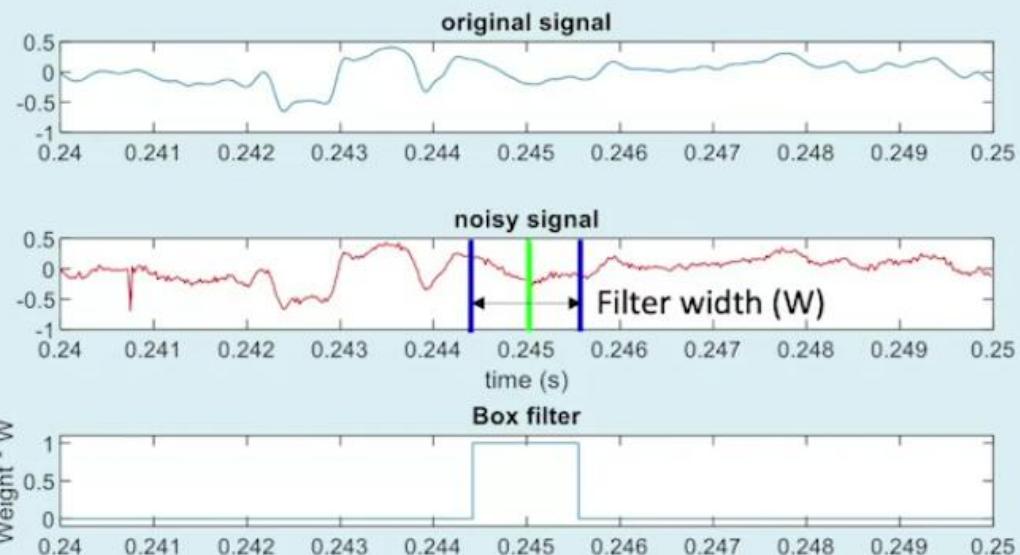


Our filter will compute a
weighted average of all of

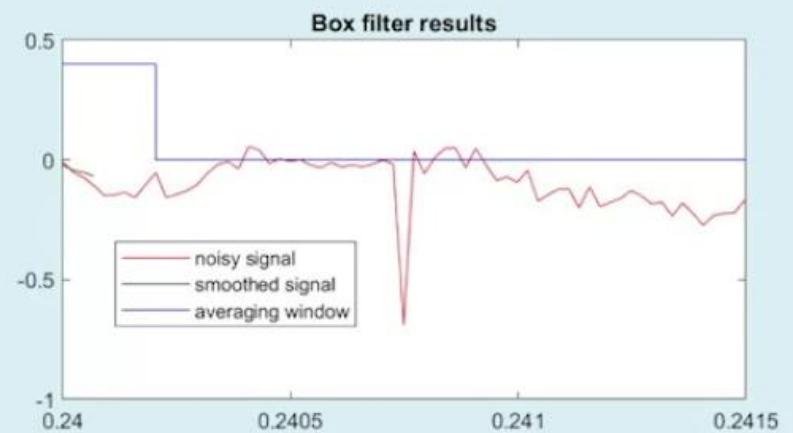


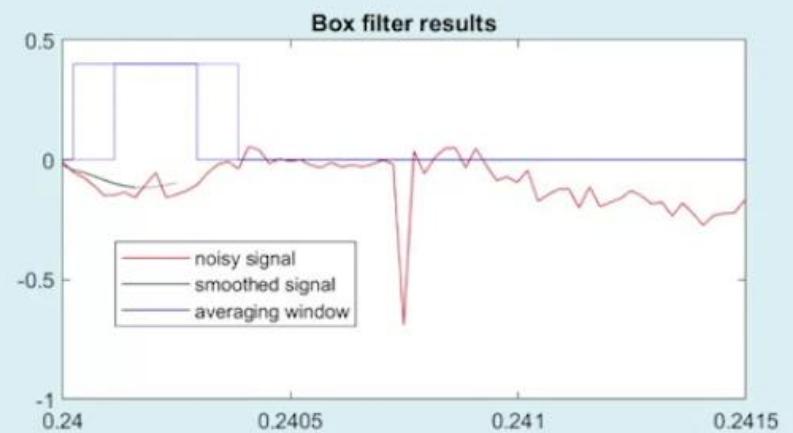


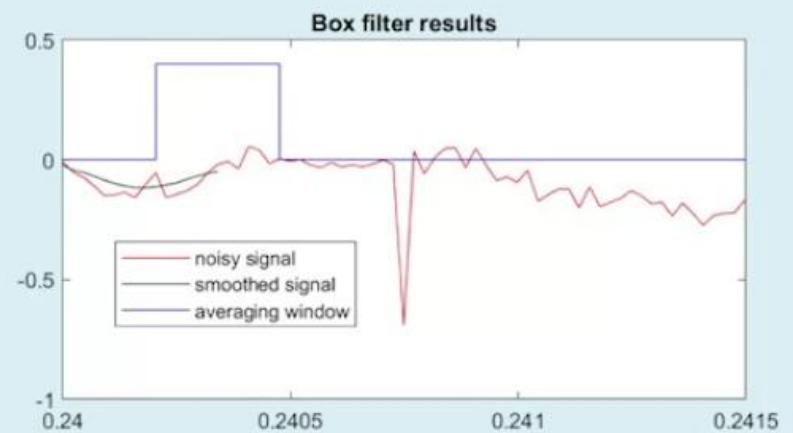
$$y_{filt}(t) = \sum_{i=0}^{W-1} \frac{1}{W} y(i + R) = \frac{1}{W} \sum_{i=0}^{W-1} y(i + R)$$

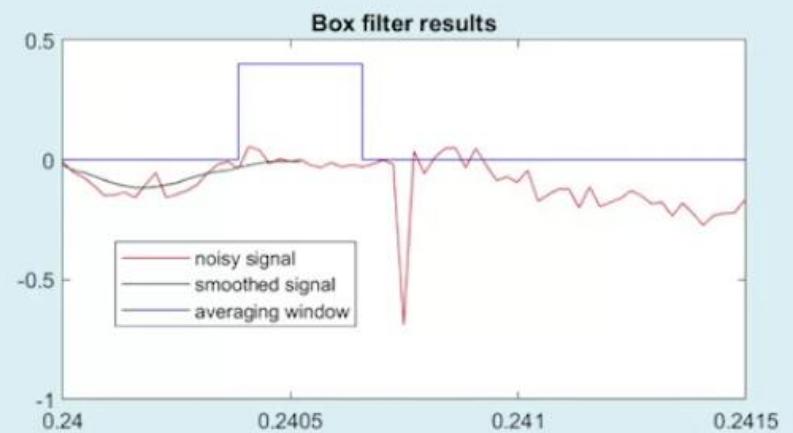


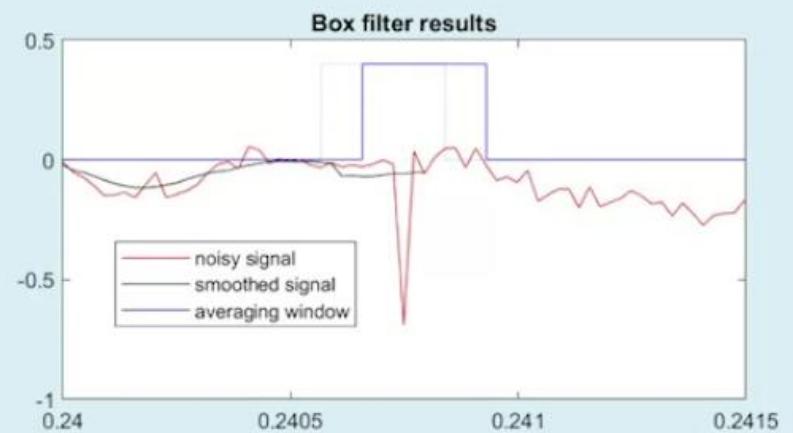
```
>> j = find(t == 0.245)
>> R = j - floor(W/2)
>> yfilt(j) = mean(y(R:R+W-1))
```

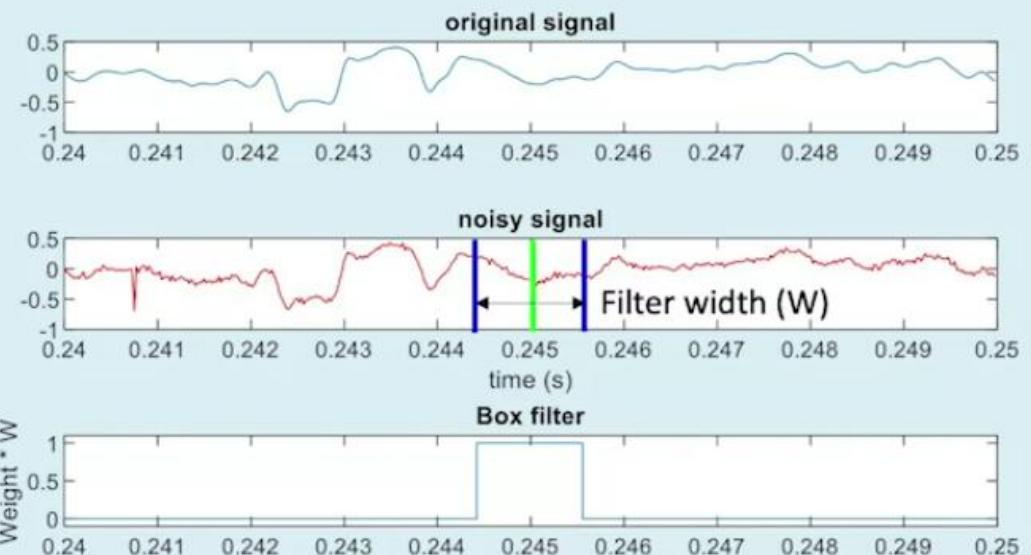




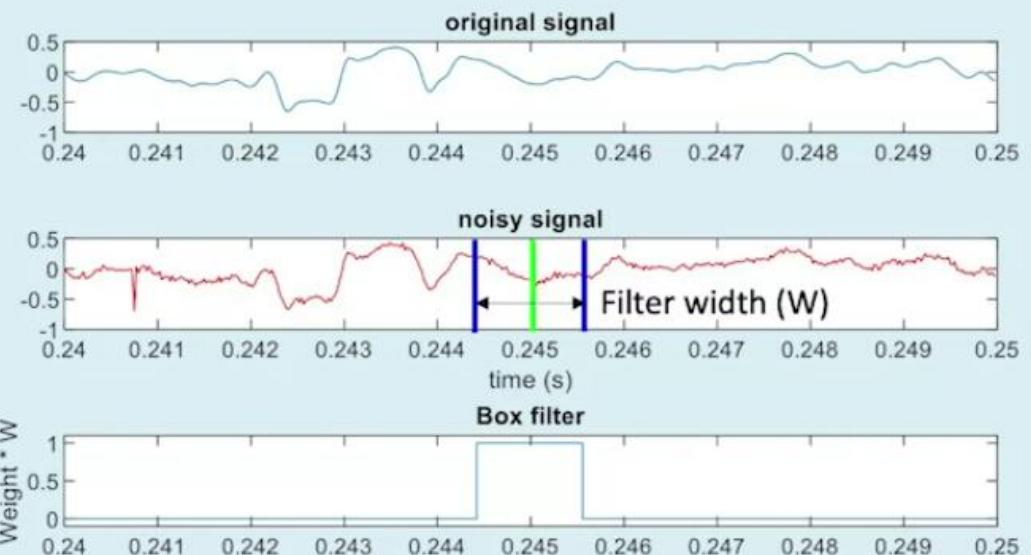








Convolution: $\text{conv}(y(t), f) = \sum_{i=-W/2}^{W/2} y(t-i)f(i)$



Convolution: `>> yfilt = conv(y, f);`

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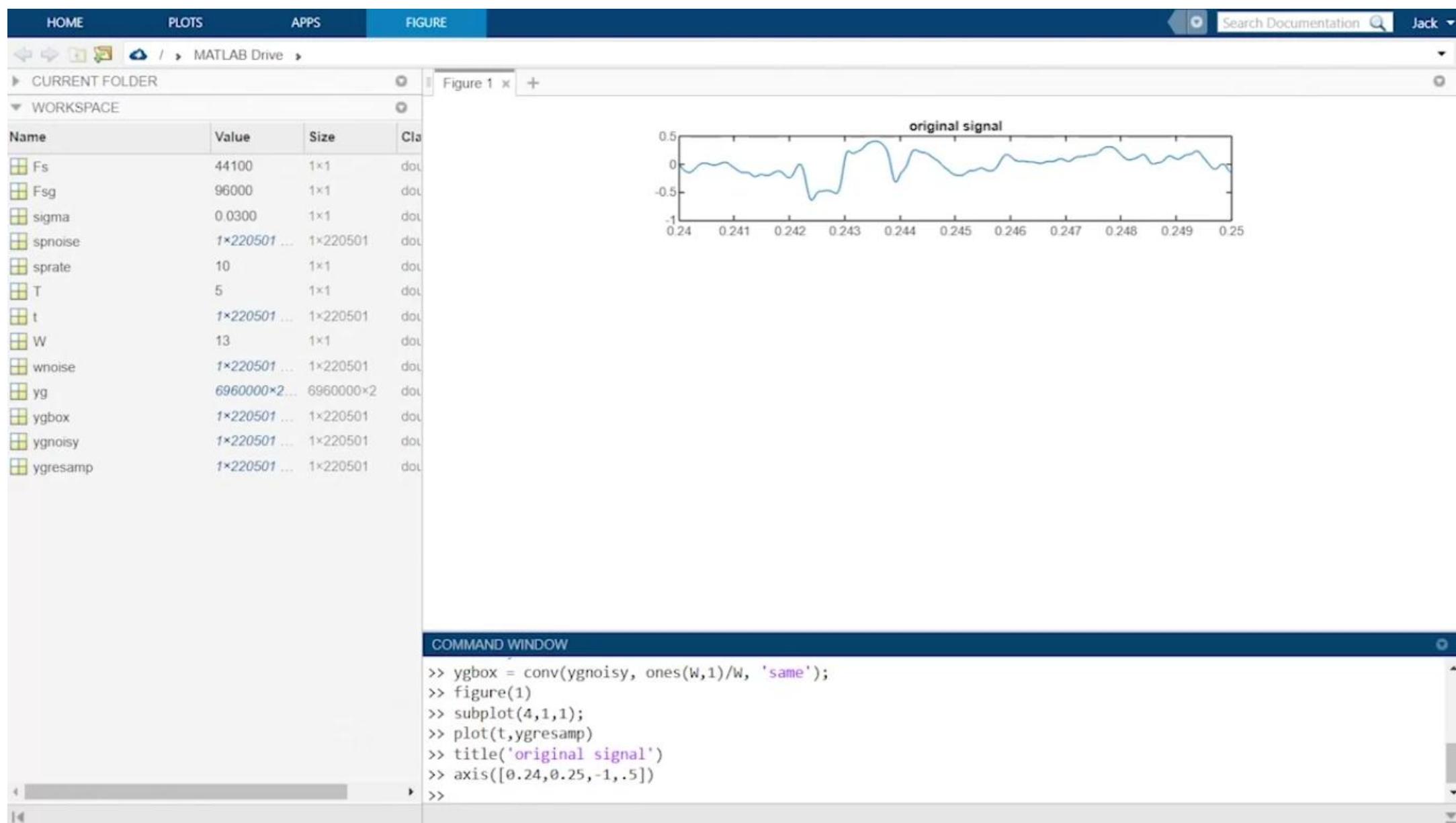
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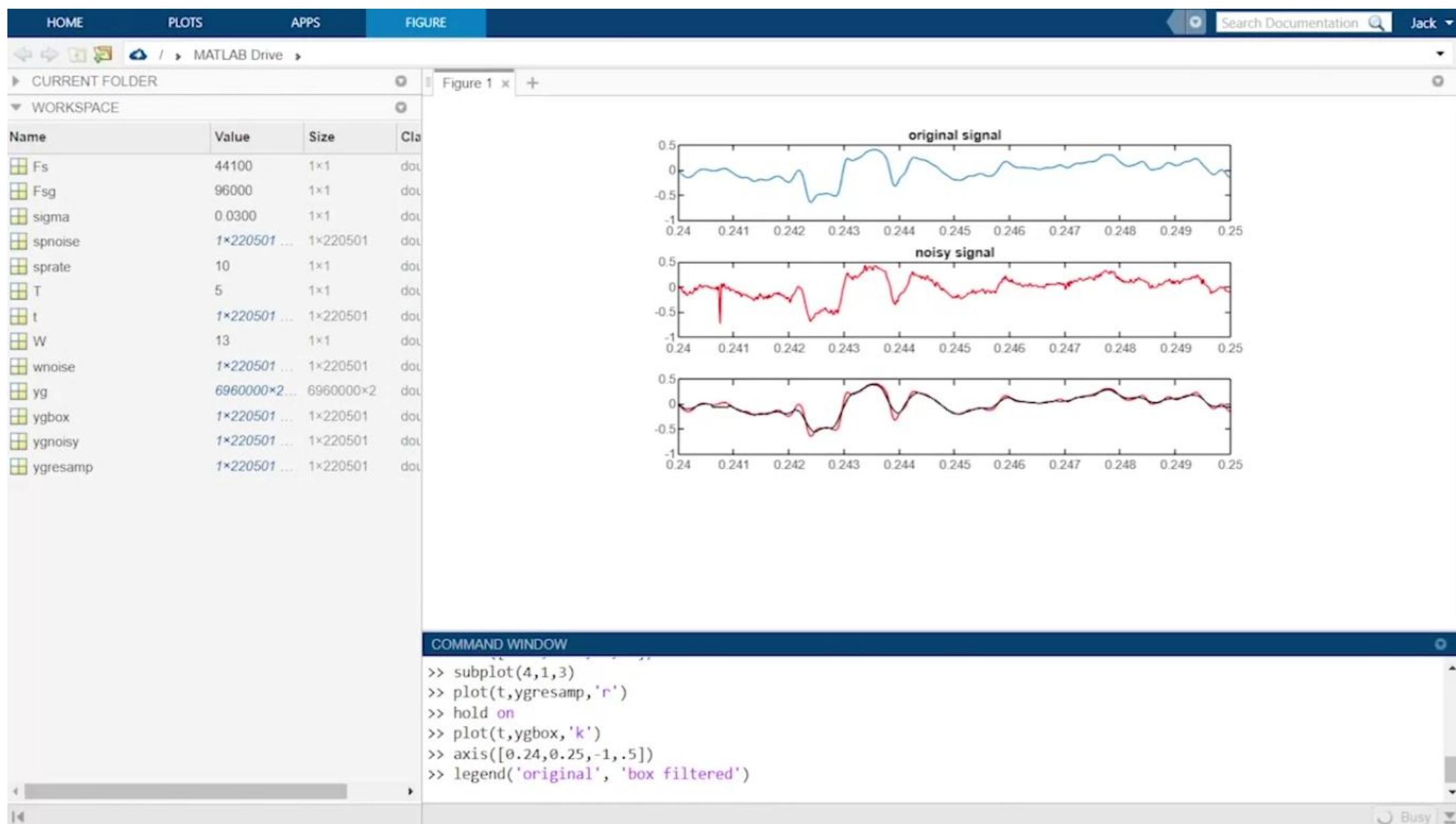
CURRENT FOLDER

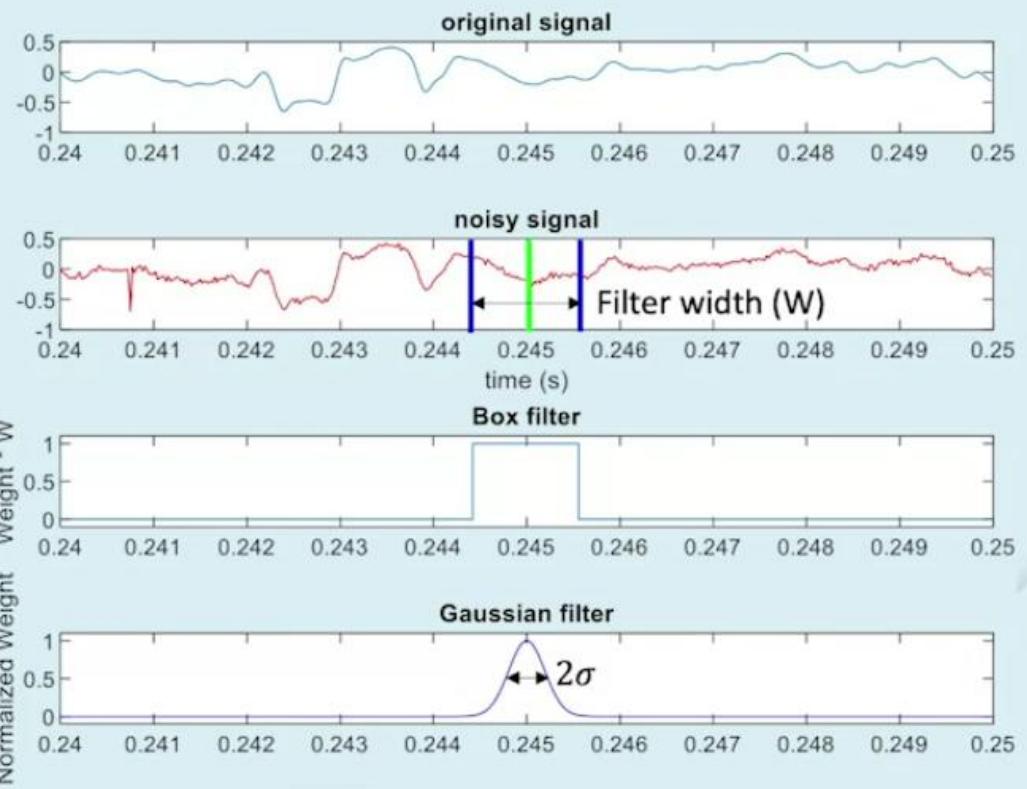
WORKSPACE

Name	Value	Size	Class
Fs	44100	1x1	double
Fsg	96000	1x1	double
sigma	0.0300	1x1	double
spnoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
W	13	1x1	double
wnoise	1x220501 ...	1x220501	double
yg	6960000x2...	6960000x2	double
ygbox	1x220501 ...	1x220501	double
ygnoisy	1x220501 ...	1x220501	double
ygresamp	1x220501 ...	1x220501	double

```
>> Fs = 44100;
>> T = 5;
>> t = [0:1/Fs:T];
>> [yg, Fsg] = audioread('RockGuitar-16-96-stereo-72secs.flac');
>> ygresamp = interp1([0:1/Fsg:(length(yg)-1)/Fsg],yg(:,1),t);
>> sprate = 10;
>> sigma = 0.03;
>> rng(0);
>> spnoise = saltpeppernoise(sprate, t, Fs);
>> wnoise = sigma*randn(size(t));
>> ygnoisy = ygresamp + spnoise + wnoise;
>> W = 13;
>> ygbox = conv(ygnoisy, ones(W,1)/W, 'same');
>>
```







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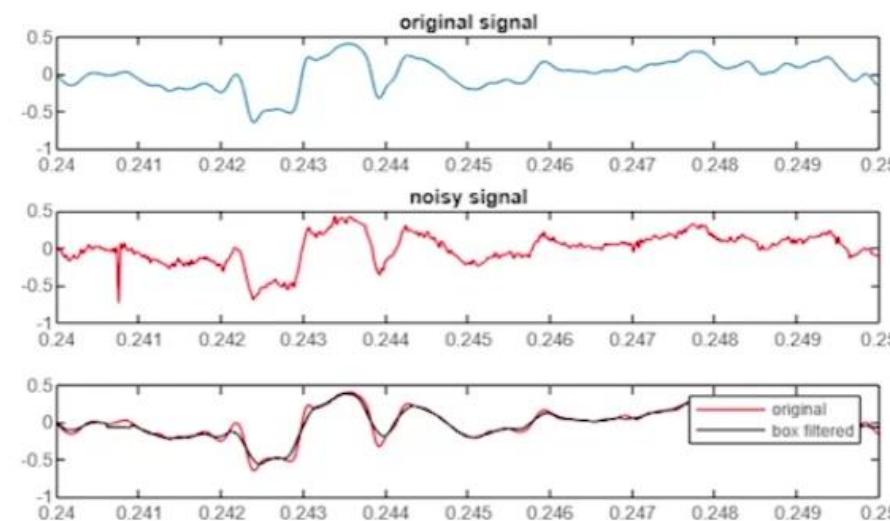
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WORKSPACE

Name	Value	Size	Class
Fs	44100	1x1	double
Fsg	96000	1x1	double
gaussianfilter	1x13 double	1x13	double
sigma	2.1667	1x1	double
snoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
W	13	1x1	double
wnoise	1x220501 ...	1x220501	double
yg	6960000x2...	6960000x2	double
ygbox	1x220501 ...	1x220501	double
ygaus	1x220501 ...	1x220501	double
ygnoisy	1x220501 ...	1x220501	double
ygresamp	1x220501 ...	1x220501	double

Figure 1 x +



COMMAND WINDOW

```
>> plot(t,ygbox,'k')
>> axis([0.24,0.25,-1,.5])
>> legend('original', 'box filtered')
>> sigma = W/6;
>> gaussianfilter = fspecial('gaussian', [1, W], sigma);
>> ygaus = conv(ygnoisy, gaussianfilter, 'same');
>> |
```

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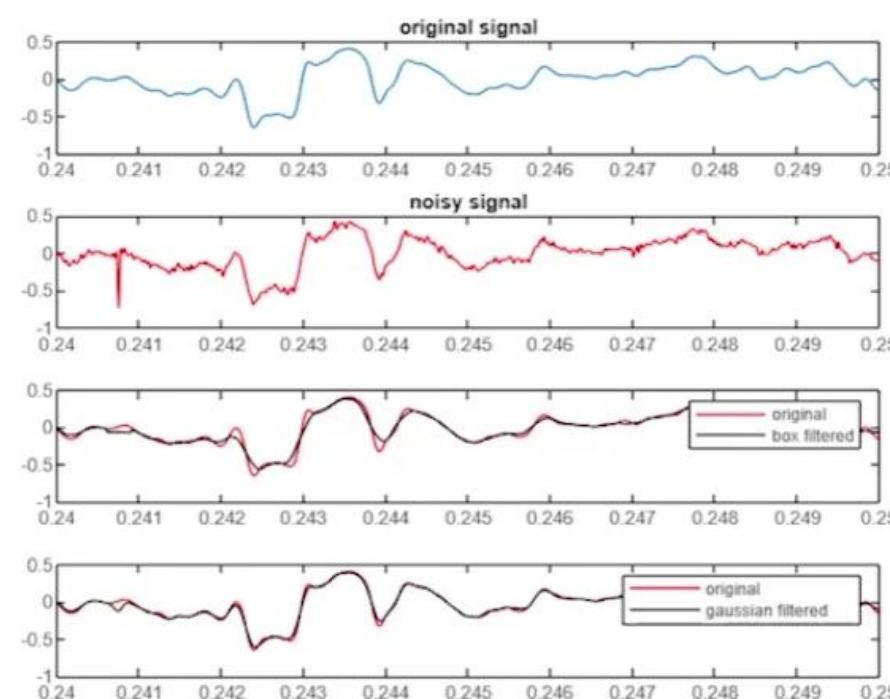
Jack

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WORKSPACE

Name	Value	Size	Class
Fs	44100	1x1	double
Fsg	96000	1x1	double
gaussianfilter	1x13 double	1x13	double
sigma	2.1667	1x1	double
snoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
W	13	1x1	double
wnoise	1x220501 ...	1x220501	double
yg	6960000x2...	6960000x2	double
ygbox	1x220501 ...	1x220501	double
yggaus	1x220501 ...	1x220501	double
ygnoisy	1x220501 ...	1x220501	double
ygresamp	1x220501 ...	1x220501	double



COMMAND WINDOW

```
>> subplot(4,1,4);
>> plot(t,ygresamp,'r')
>> hold on
>> plot(t,yggaus,'k')
>> axis([0.24,0.25,-1,.5])
>> legend('original', 'gaussian filtered')
>>
```

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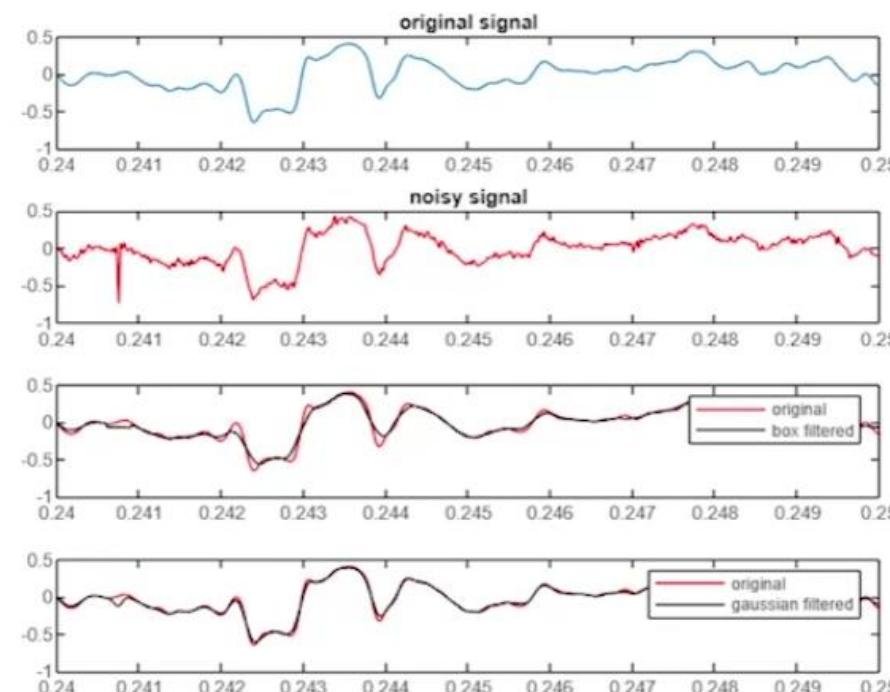
Jack

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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
Fs	44100	1x1	double
Fsg	96000	1x1	double
gaussianfilter	1x13 double	1x13	double
sigma	2.1667	1x1	double
snoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
W	13	1x1	double
wnoise	1x220501 ...	1x220501	double
yg	6960000x2...	6960000x2	double
ygbox	1x220501 ...	1x220501	double
yggaus	1x220501 ...	1x220501	double
ygnosy	1x220501 ...	1x220501	double
ygresamp	1x220501 ...	1x220501	double



COMMAND WINDOW

```
>> axis([0.24,0.25,-1,.5])
>> legend('original', 'gaussian filtered')
>> soundsc(ygresamp, Fs)
>> soundsc(ygnosy, Fs)
>> soundsc(ygbox, Fs)
>> soundsc(yggaus, Fs)
>>
```

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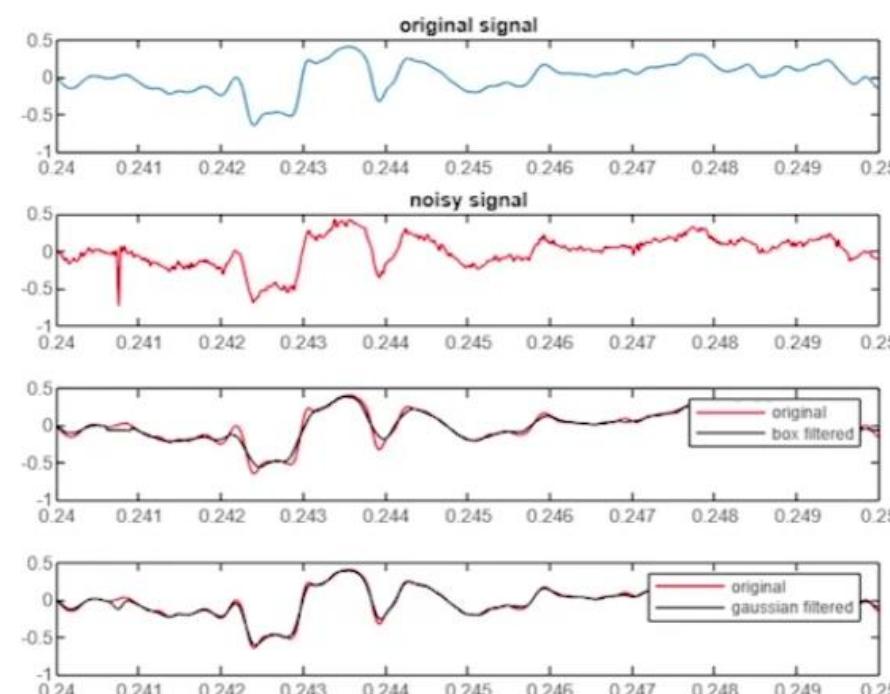
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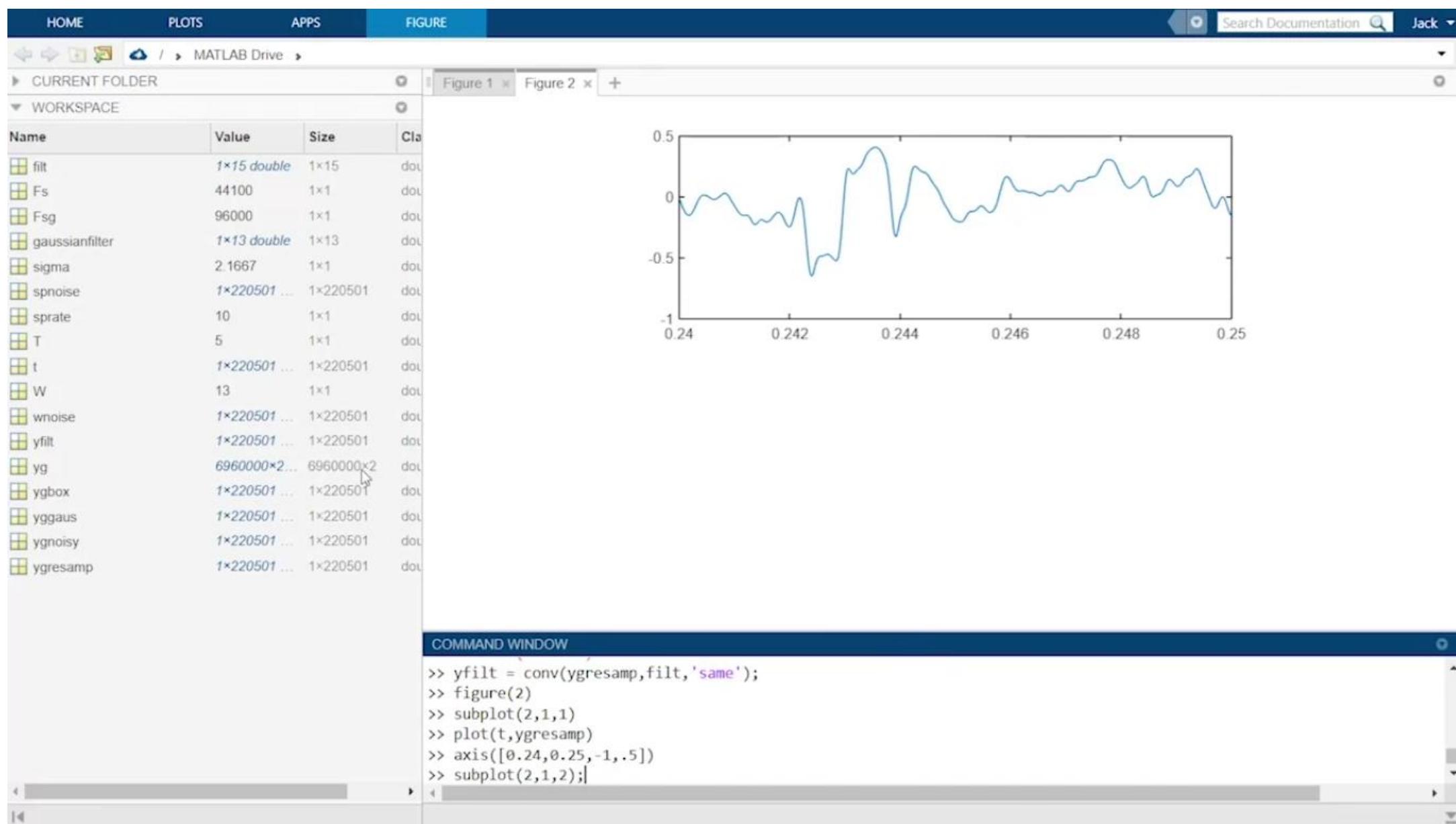
Name	Value	Size	Class
filter	1x15 double	1x15	double
Fs	44100	1x1	double
Fsg	96000	1x1	double
gaussianfilter	1x13 double	1x13	double
sigma	2.1667	1x1	double
spnoise	1x220501 ...	1x220501	double
sprate	10	1x1	double
T	5	1x1	double
t	1x220501 ...	1x220501	double
W	13	1x1	double
wnoise	1x220501 ...	1x220501	double
yg	6960000x2...	6960000x2	double
ygbox	1x220501 ...	1x220501	double
yggaus	1x220501 ...	1x220501	double
ygnoisy	1x220501 ...	1x220501	double
ygresamp	1x220501 ...	1x220501	double

Figure 1 x +

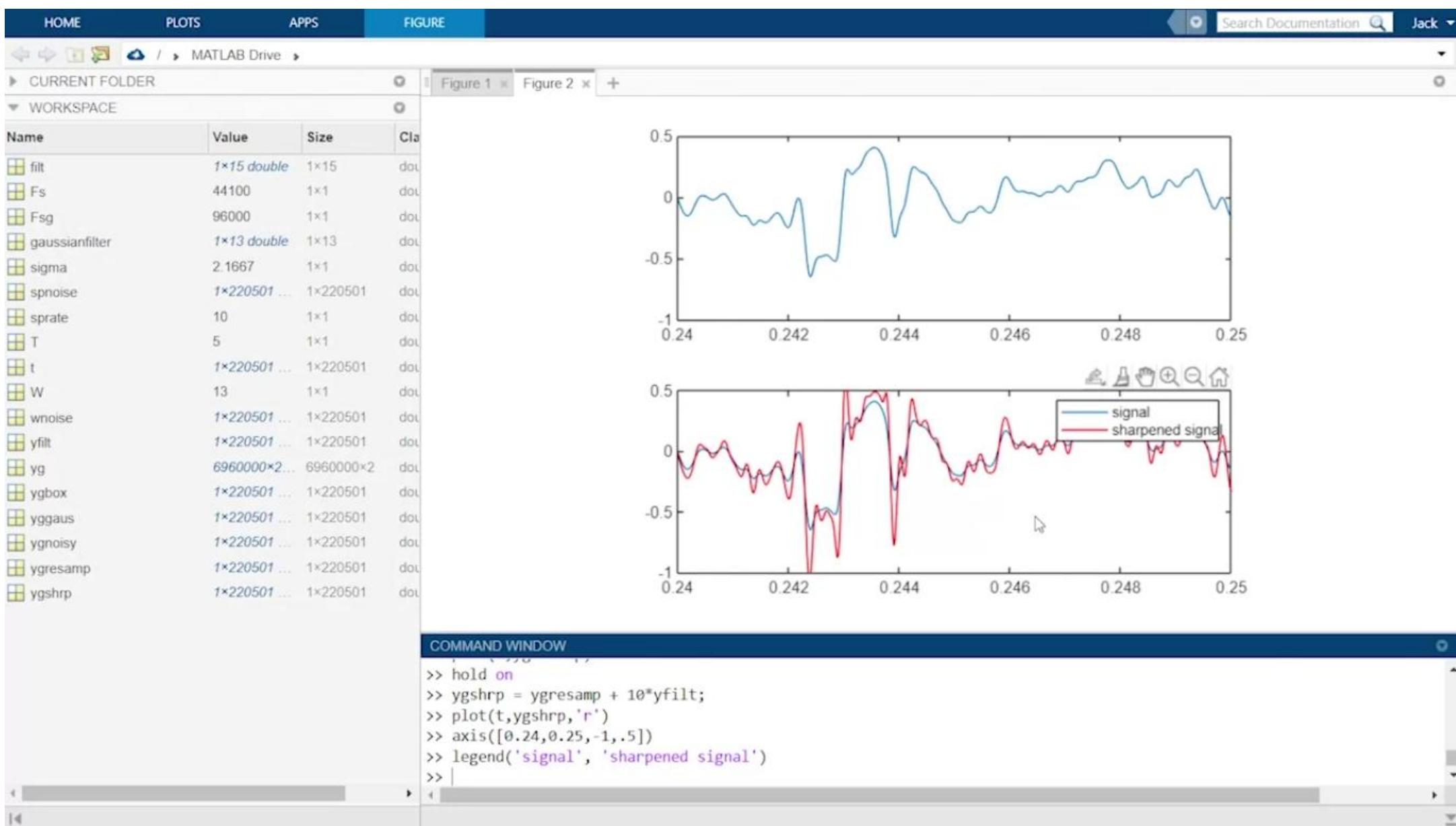


COMMAND WINDOW

```
>> soundsc(yggaus, 1.5)
>> filt = fir1(W,5000/(Fs/2),'high');
Warning: Odd order symmetric FIR filters must have a gain of zero at the Nyquist frequency. The order is being increased by one.
> In fir1>eFir1 (line 142)
    In fir1 (line 92)
>>
```







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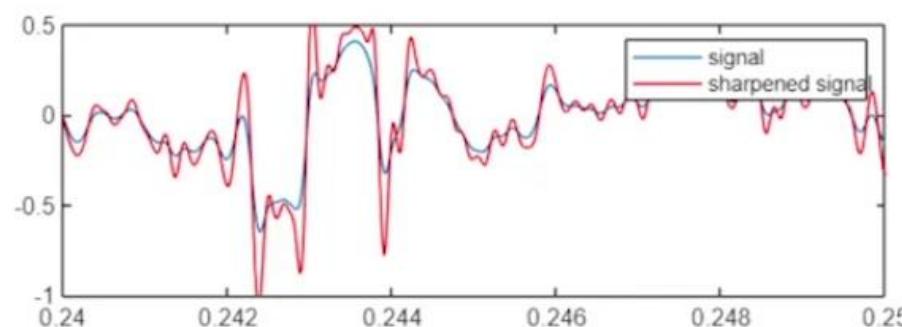
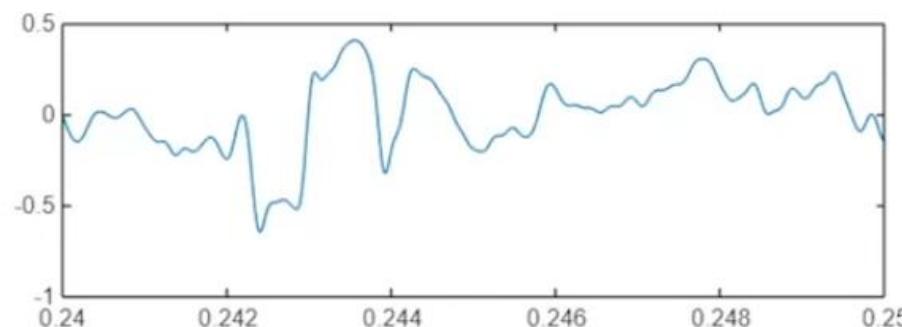
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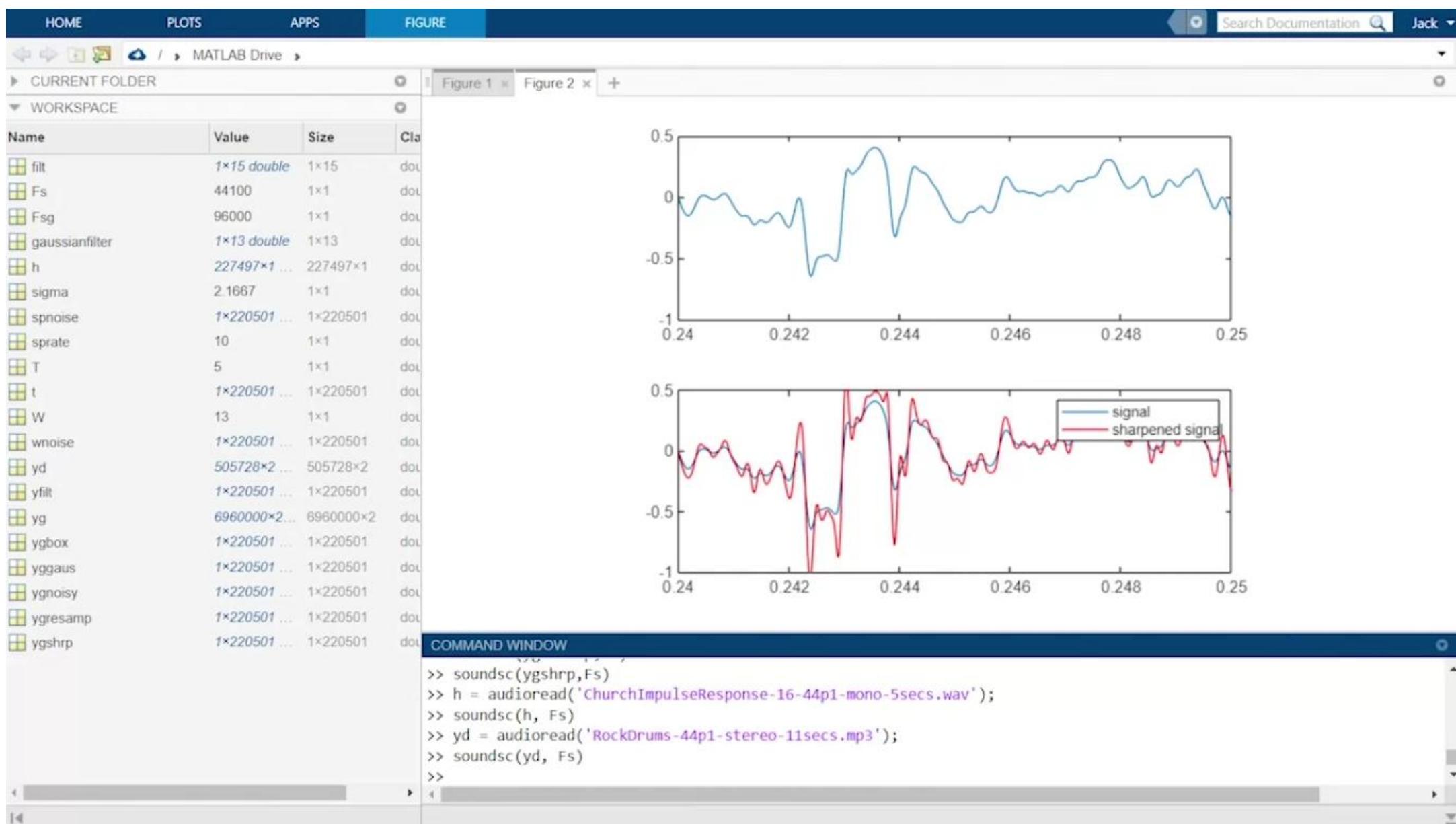
Name	Value	Size	Class
filt	1×15 double	1×15	double
Fs	44100	1×1	double
Fsg	96000	1×1	double
gaussianfilter	1×13 double	1×13	double
h	227497×1 double	227497×1	double
sigma	2.1667	1×1	double
snoise	1×220501 double	1×220501	double
sprate	10	1×1	double
T	5	1×1	double
t	1×220501 double	1×220501	double
W	13	1×1	double
wnoise	1×220501 double	1×220501	double
yfilt	1×220501 double	1×220501	double
yg	6960000×2 double	6960000×2	double
ygbox	1×220501 double	1×220501	double
yggaus	1×220501 double	1×220501	double
ygnoisy	1×220501 double	1×220501	double
ygresamp	1×220501 double	1×220501	double
ygshrp	1×220501 double	1×220501	double

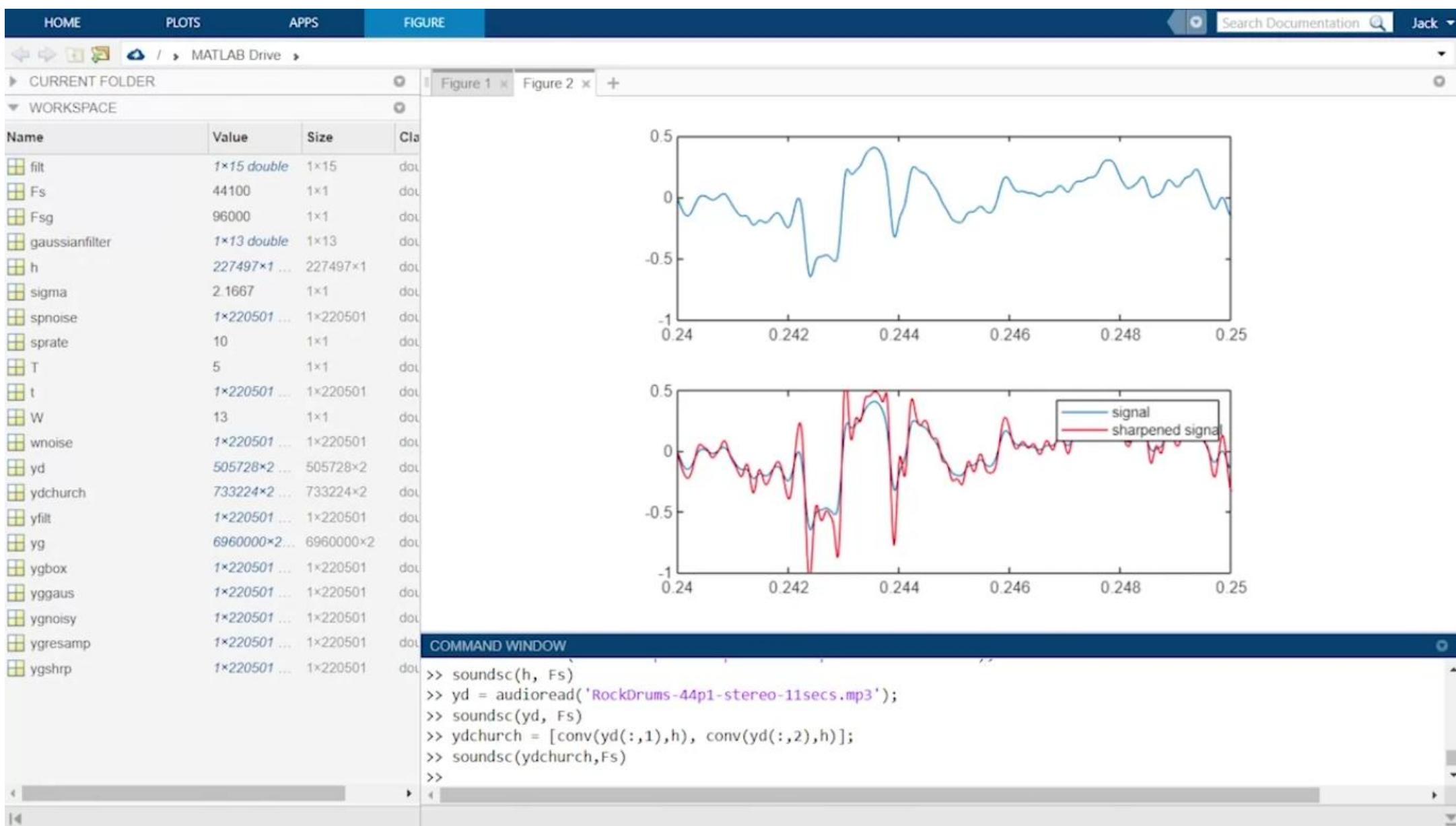
Figure 1 < Figure 2 +



COMMAND WINDOW

```
>> legend('signal', 'sharpened signal')
>> soundsc(ygresamp,Fs)
>> soundsc(ygshrp,Fs)
>> h = audioread('ChurchImpulseResponse-16-44p1-mono-5secs.wav');
>> soundsc(h, Fs)
>>
```







Joseph Fourier



Introduction to Data, Signal, and Image Analysis with Matlab



```
>> yfft = fft(y);  
  
>> y = ifft(yfft);
```

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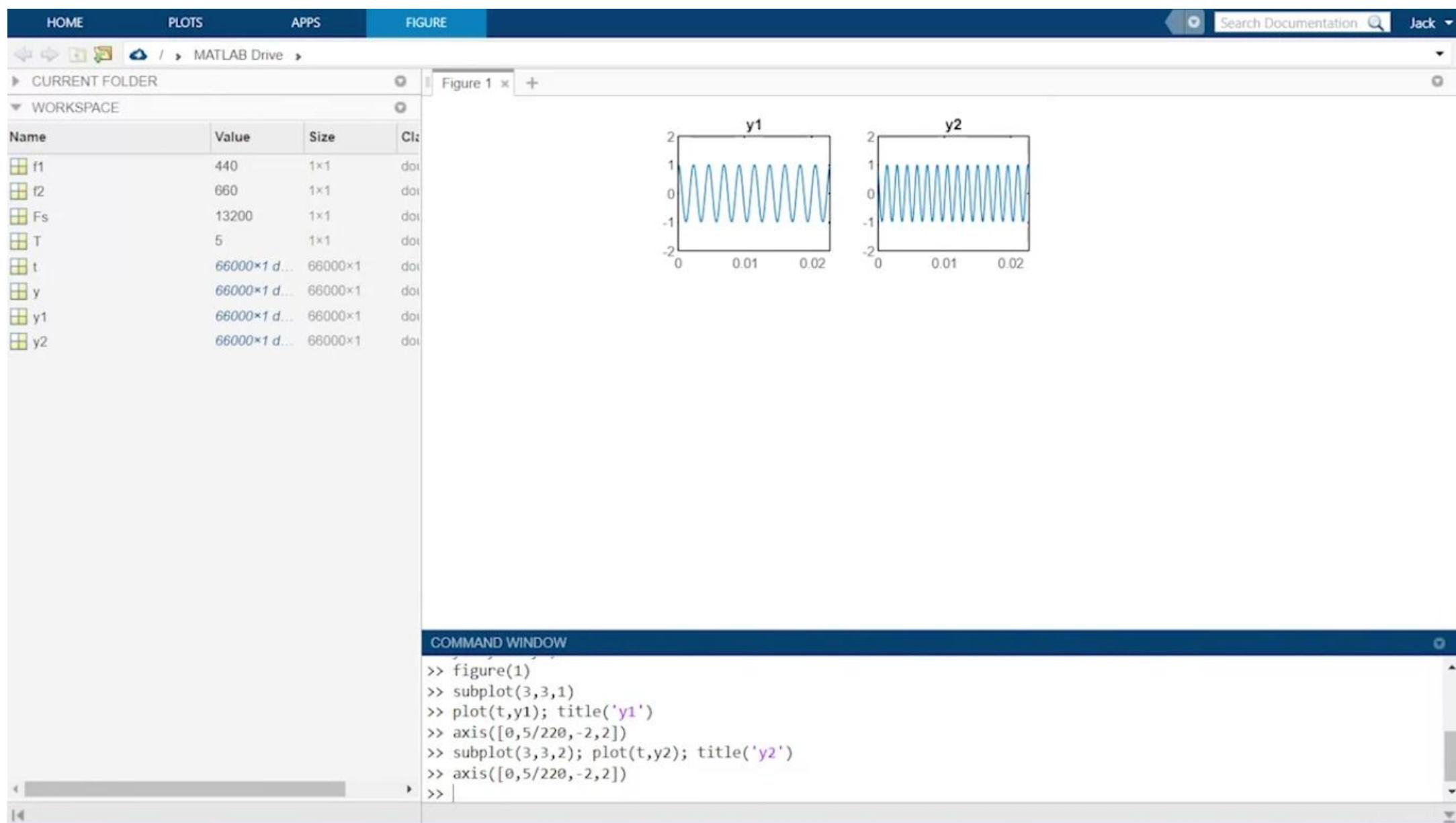
Jack

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WORKSPACE

Name	Value	Size	Class
f1	440	1x1	double
f2	660	1x1	double
Fs	13200	1x1	double
T	5	1x1	double
t	66000x1 double	66000x1	double
y	66000x1 double	66000x1	double
y1	66000x1 double	66000x1	double
y2	66000x1 double	66000x1	double

```
>> Fs = 13200;
>> f1 = 440;
>> f2 = 660;
>> T = 5;
>> t = [0:1/Fs:T-1/Fs]';
>> y1 = cos(2*pi*f1*t);
>> y2 = cos(2*pi*f2*t + pi/4);
>> y = y1 + y2;
>>
```



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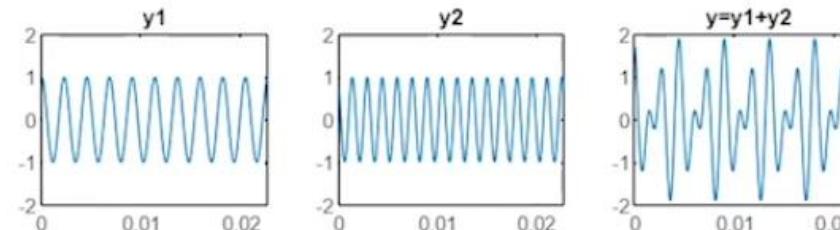
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WORKSPACE

Name	Value	Size	Class
f1	440	1x1	double
f2	660	1x1	double
Fs	13200	1x1	double
T	5	1x1	double
t	66000x1 double	66000x1	double
y	66000x1 double	66000x1	double
y1	66000x1 double	66000x1	double
y2	66000x1 double	66000x1	double
loading	loading...	loading...	loading

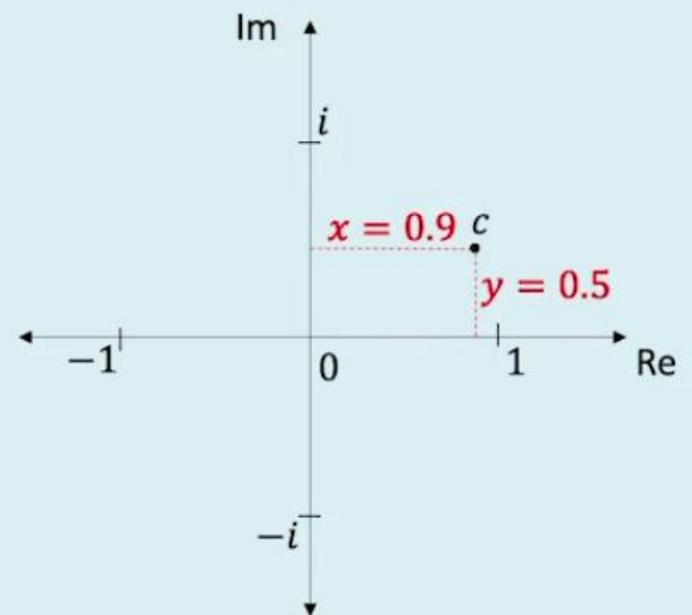
Figure 1 x +



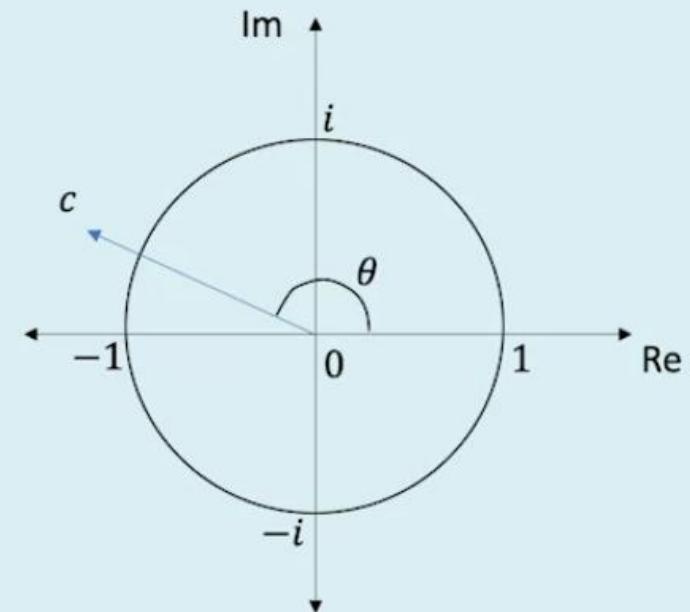
COMMAND WINDOW

```
>> subplot(3,3,3); plot(t,y); title('y=y1+y2')
>> axis([0,5/220,-2,2])
>> soundsc(y1,Fs)
>> soundsc(y2,Fs)
>> soundsc(y,Fs)
>> yfft = fft(y);
>> |
```

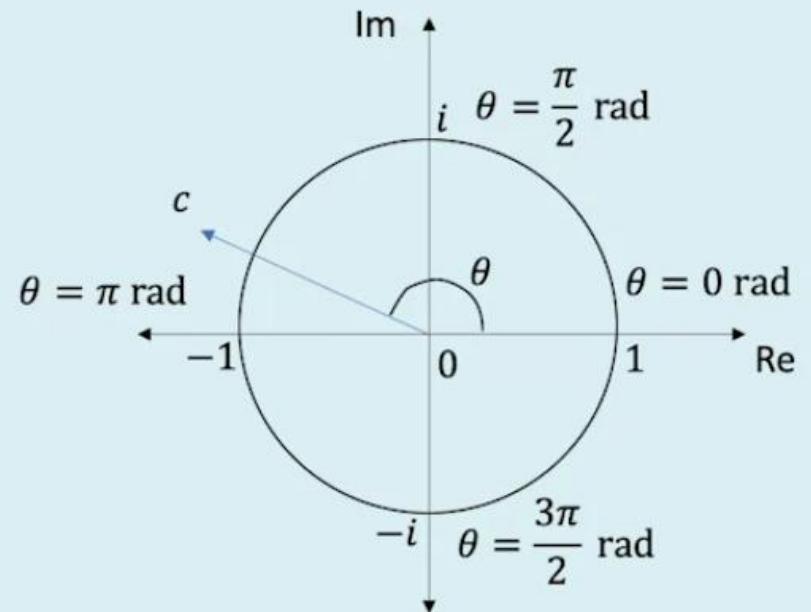
-0.3279 + 0.0000i
-0.2400 - 0.1688i
-0.0968 - 0.2399i
0.0214 - 0.1351i
0.0650 - 0.0395i
-0.0226 - 0.0116i
-0.0271 - 0.0200i
-0.0379 - 0.0824i
-0.0018 - 0.0435i
0.0363 - 0.0160i



$$c = x + iy$$
$$c = 0.9 + 0.5i$$



$$c = x + iy \quad |c| = \sqrt{x^2 + y^2}$$
$$x = |c|\cos(\theta) \quad \theta = \tan^{-1} \frac{y}{x}$$
$$y = |c|\sin(\theta)$$



$$\begin{aligned}c &= x + iy & |c| &= \sqrt{x^2 + y^2} \\x &= |c|\cos(\theta) & \theta &= \tan^{-1} \frac{y}{x} \\y &= |c|\sin(\theta)\end{aligned}$$

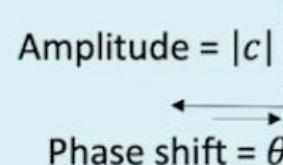
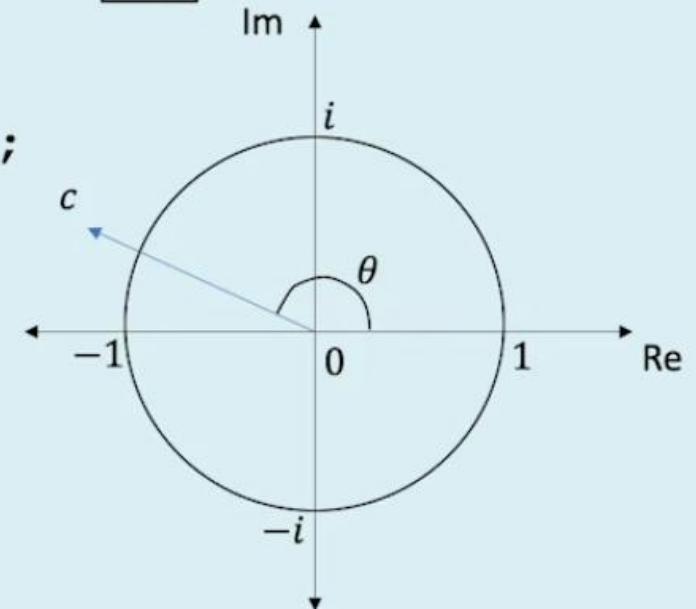


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```
>> yfft = fft(y);
```

```
-0.3279 + 0.0000i  
-0.2400 - 0.1688i  
-0.0968 - 0.2399i  
0.0214 - 0.1351i  
0.0650 - 0.0395i  
-0.0226 - 0.0116i  
-0.0271 - 0.0200i  
-0.0379 - 0.0824i  
-0.0018 - 0.0435i  
0.0363 - 0.0160i
```



A diagram showing a sine wave oscillating along a horizontal axis. A vertical dashed line from the peak of the wave to the axis is labeled "Amplitude = $|c|$ ". A double-headed arrow along the horizontal axis between two consecutive peaks is labeled "Phase shift = θ ".

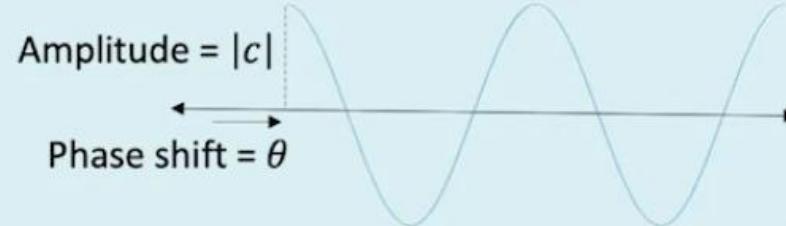
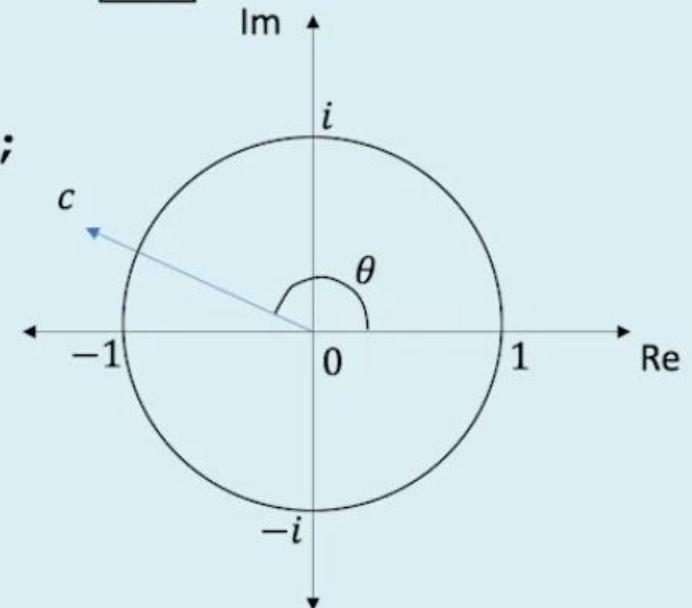


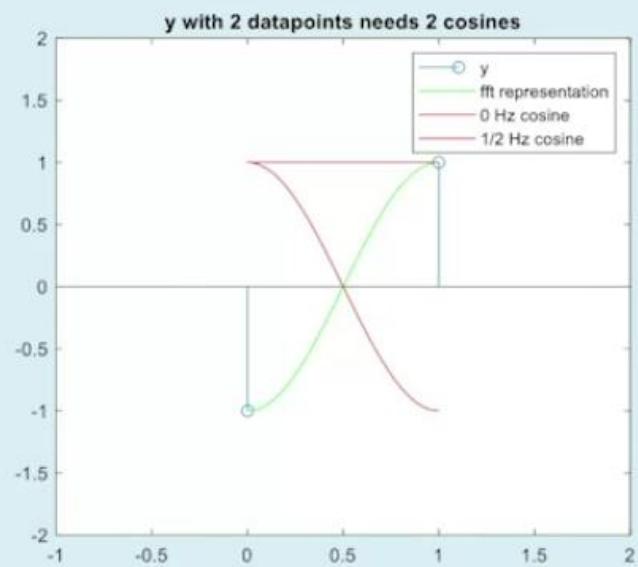
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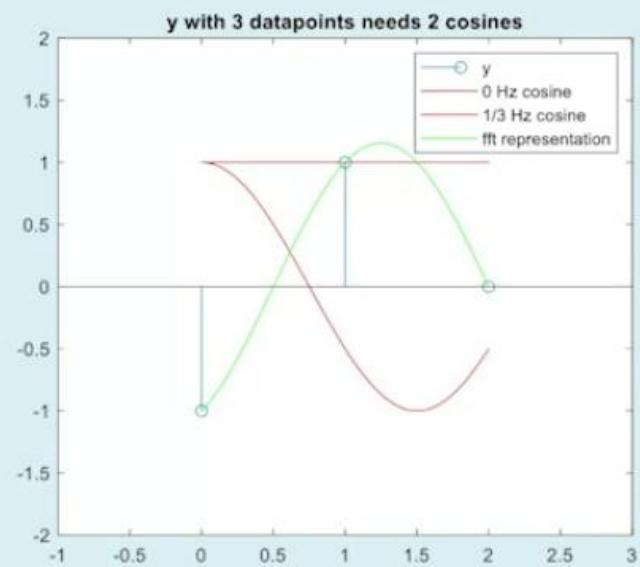
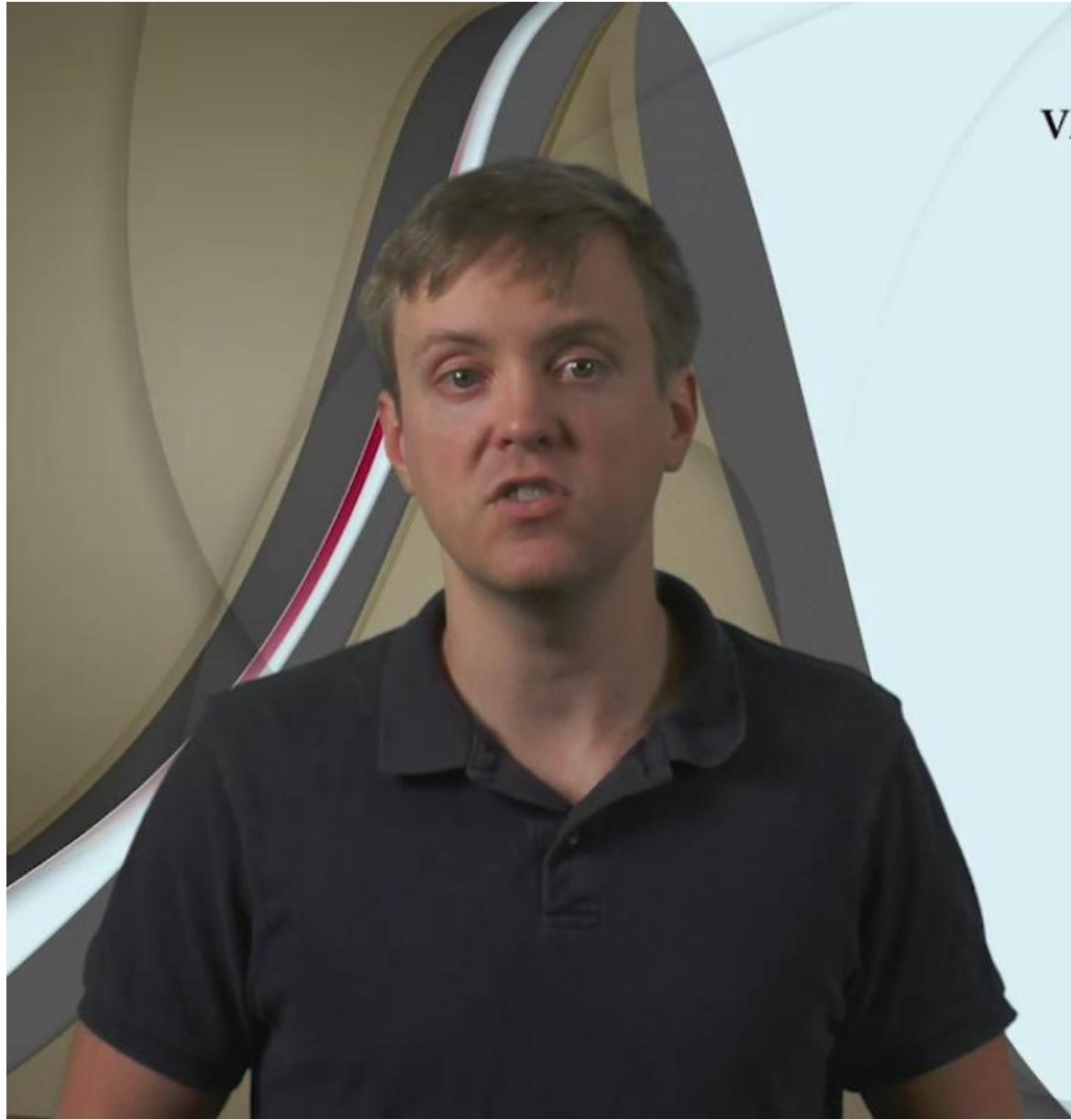
```
>> yfft = fft(y);
```

```
-0.3279 + 0.0000i  
-0.2400 - 0.1688i  
-0.0968 - 0.2399i  
0.0214 - 0.1351i  
0.0650 - 0.0395i  
-0.0226 - 0.0116i  
-0.0271 - 0.0200i  
-0.0379 - 0.0824i  
-0.0018 - 0.0435i  
0.0363 - 0.0160i
```

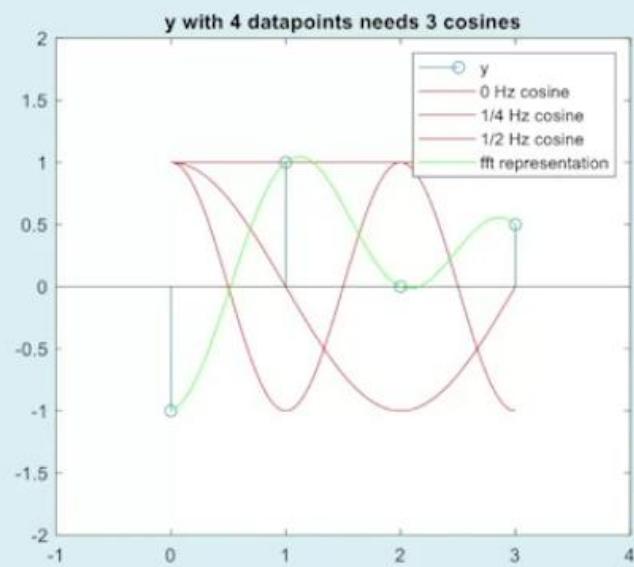
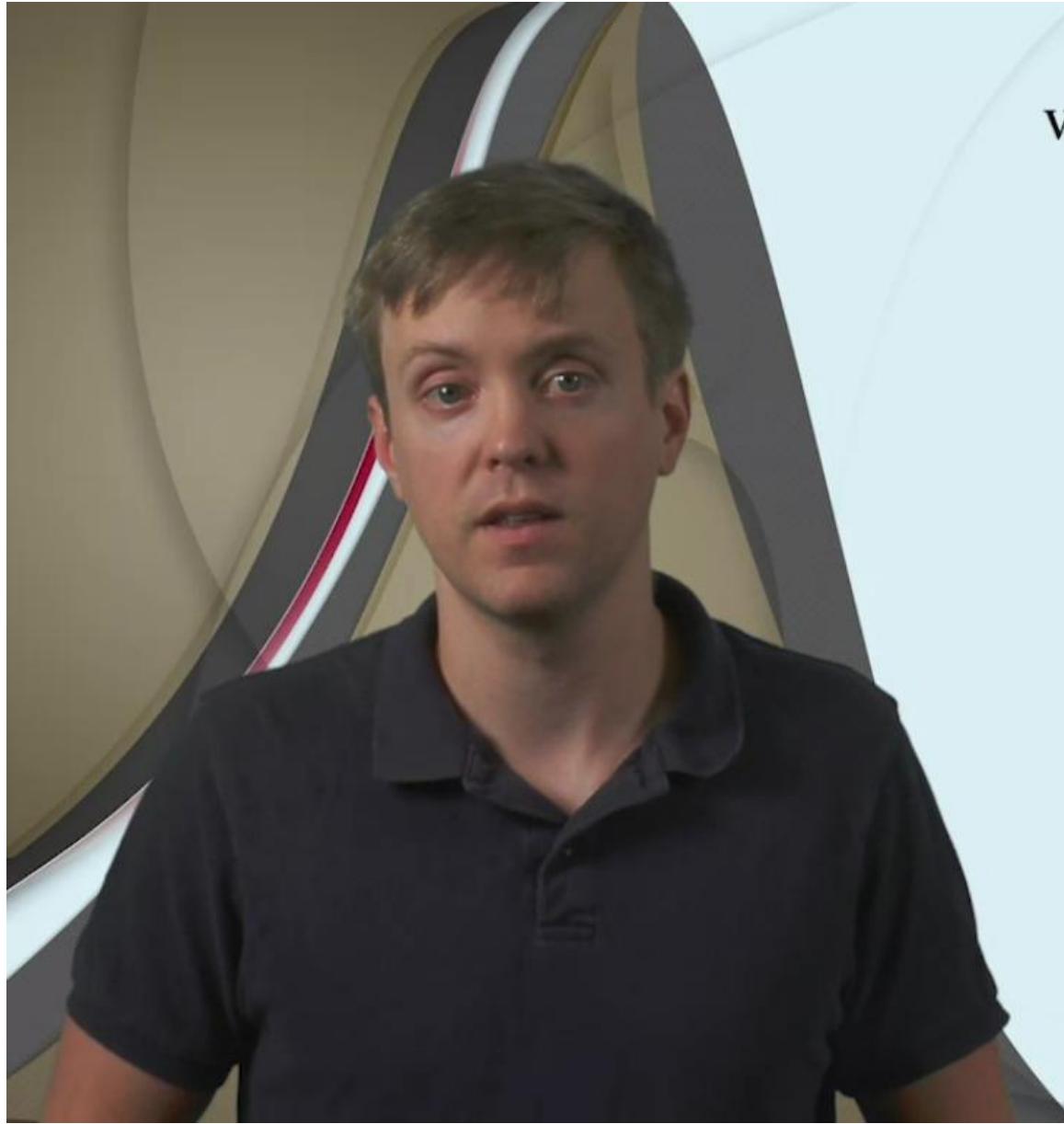




$$y(t) = 0\cos(0t) + 1\cos\left(2\pi \frac{1}{2}t + \pi\right)$$
$$: t \in [0,1]$$

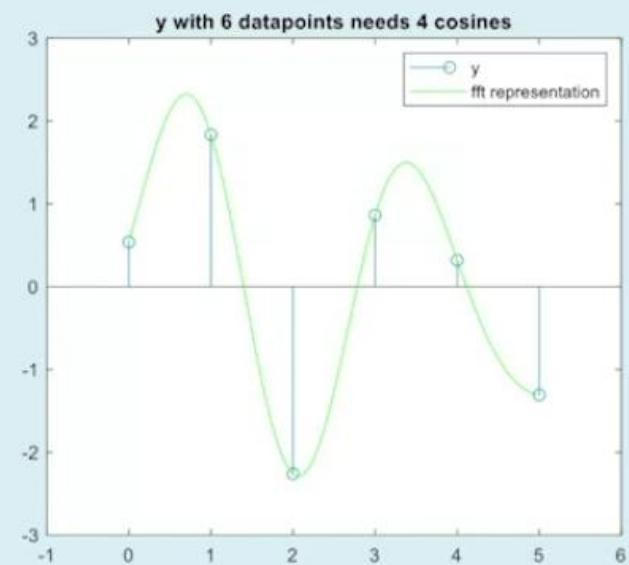


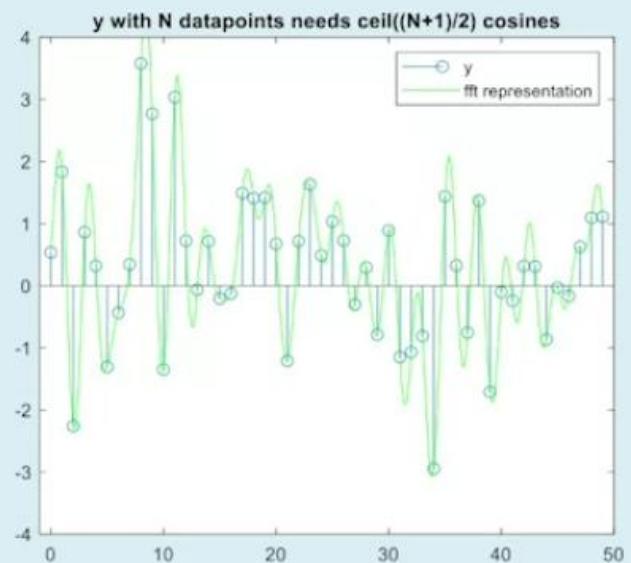
$$y(t) = 0\cos(0t) + \left(\frac{2\sqrt{3}}{3}\right) \cos\left(2\pi \frac{1}{3}t + \frac{-5\pi}{6}\right)$$
$$: t \in [0,1,2]$$



$$y(t) = \frac{1}{8} \cos(0t) + \left(\frac{\sqrt{5}}{4}\right) \cos\left(2\pi \frac{1}{4}t - 0.8524\pi\right) \\ + \left(\frac{5}{8}\right) \cos\left(2\pi \frac{1}{2}t + \pi\right); t \in [0,1,2,3]$$







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Name	Value	Size
ans	[-3.2787e-10, -2.4003e-10 ...]	10x1
f1	440	1x1
f2	660	1x1
Fs	13200	1x1
T	5	1x1
t	66000x1 double	66000x1
y	66000x1 double	66000x1
y1	66000x1 double	66000x1
y2	66000x1 double	66000x1
yfft	66000x1 complex double	66000x1

```
1 | function [yfft, f] = myfft(y,Fs)
2 |     yfft = fft(y);
3 |     yfft = yfft(1:ceil((length(y)+1)/2));
4 |     sampnum = [0:(length(yfft)-1)]';
5 |     f = sampnum*Fs/length(y);
6 | end
```

COMMAND WINDOW

```
-0.3279 + 0.0000i
-0.2400 - 0.1688i
-0.0968 - 0.2399i
0.0214 - 0.1351i
0.0650 - 0.0395i
-0.0226 - 0.0116i
-0.0271 - 0.0200i
-0.0379 - 0.0824i
-0.0018 - 0.0435i
0.0363 - 0.0160i
```

```
>> edit
>>
```

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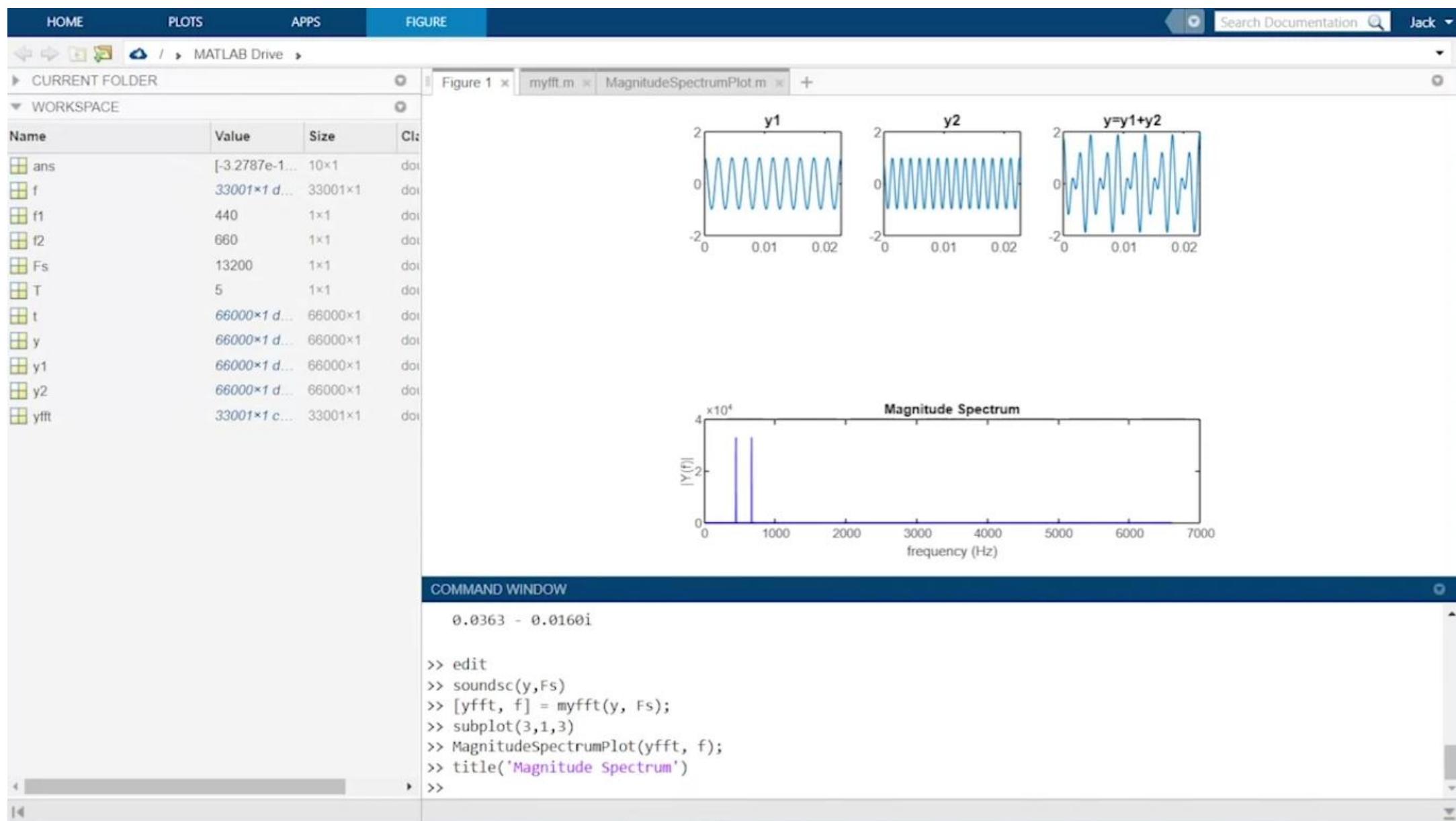
Name	Value	Size
ans	[-3.2787e-10, -2.4003e-10 ...]	10x1
f	33001x1 double	33001x1
f1	440	1x1
f2	660	1x1
Fs	13200	1x1
T	5	1x1
t	66000x1 double	66000x1
y	66000x1 double	66000x1
y1	66000x1 double	66000x1
y2	66000x1 double	66000x1
yfft	33001x1 complex double	33001x1

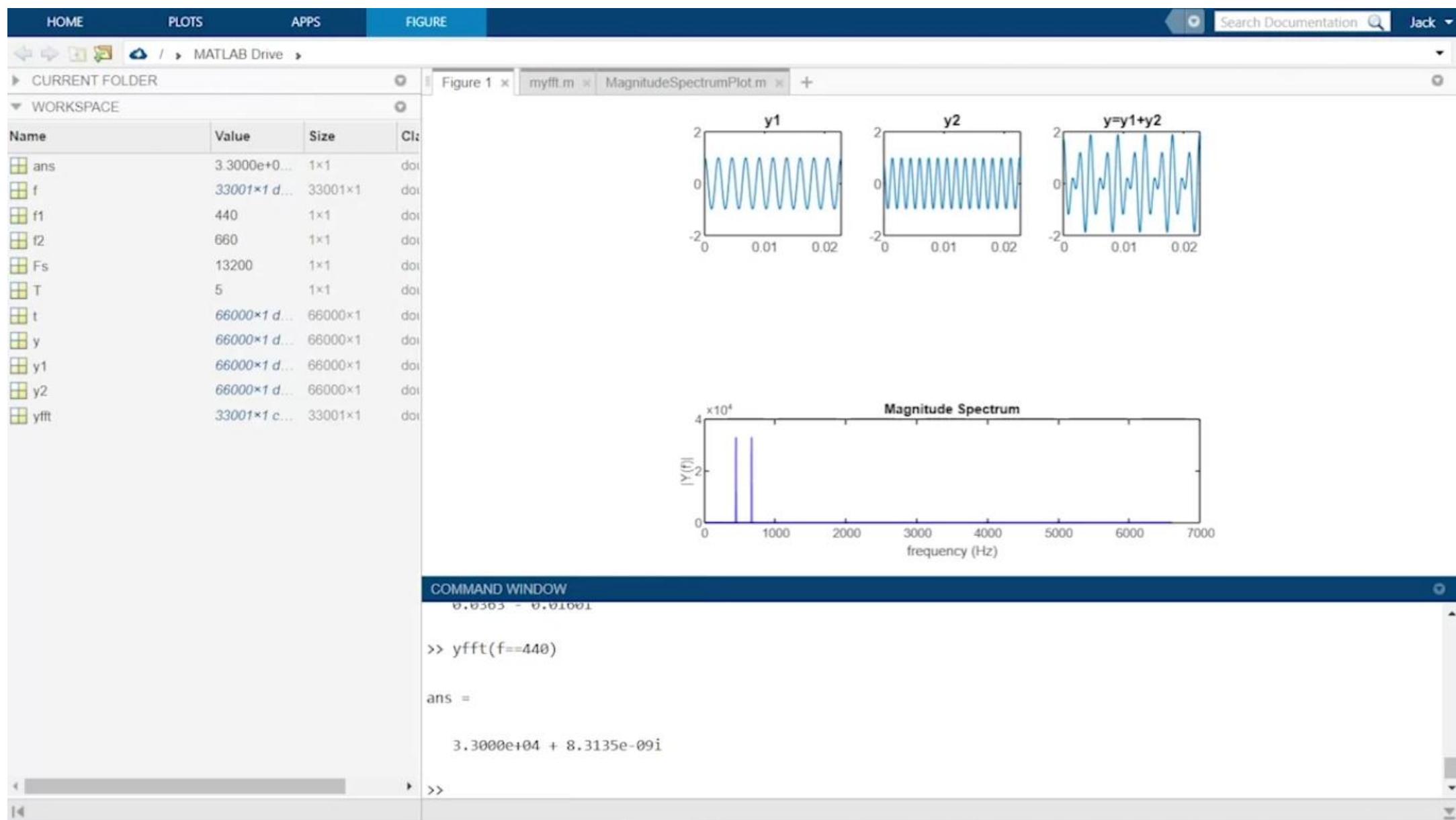
```
1 | function MagnitudeSpectrumPlot(yfft, f, col)
2 |     if nargin<3
3 |         col = 'b';
4 |     end
5 |     plot(f, abs(yfft), col);
6 |     xlabel('frequency (Hz)')
7 |     ylabel('|Y(f)|')
8 | end
```

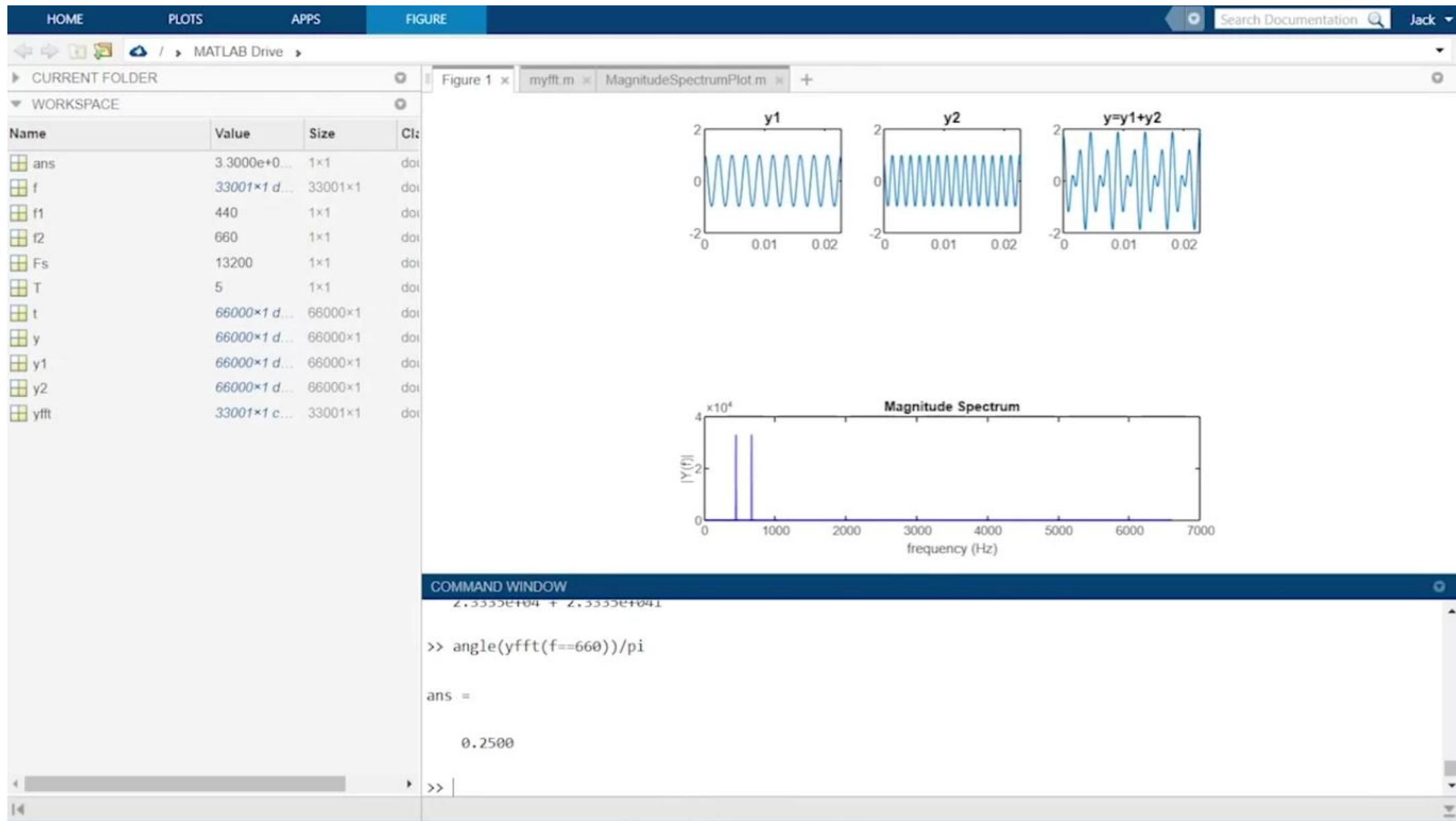
COMMAND WINDOW

```
-0.3279 + 0.0000i
-0.2400 - 0.1688i
-0.0968 - 0.2399i
0.0214 - 0.1351i
0.0650 - 0.0395i
-0.0226 - 0.0116i
-0.0271 - 0.0200i
-0.0379 - 0.0824i
-0.0018 - 0.0435i
0.0363 - 0.0160i

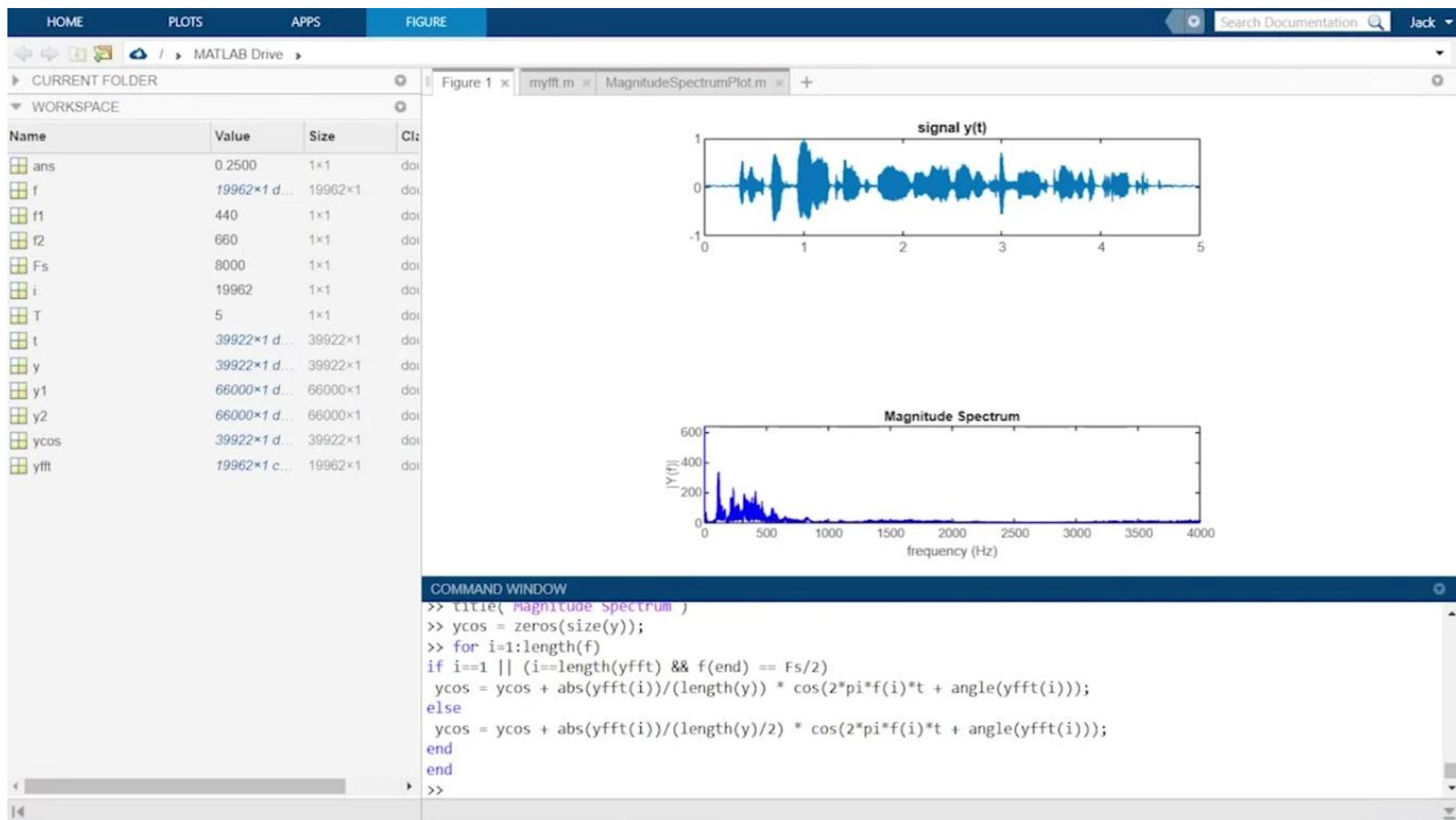
>> edit
>> soundsc(y,Fs)
>> [yfft, f] = myfft(y, Fs);
>>
```

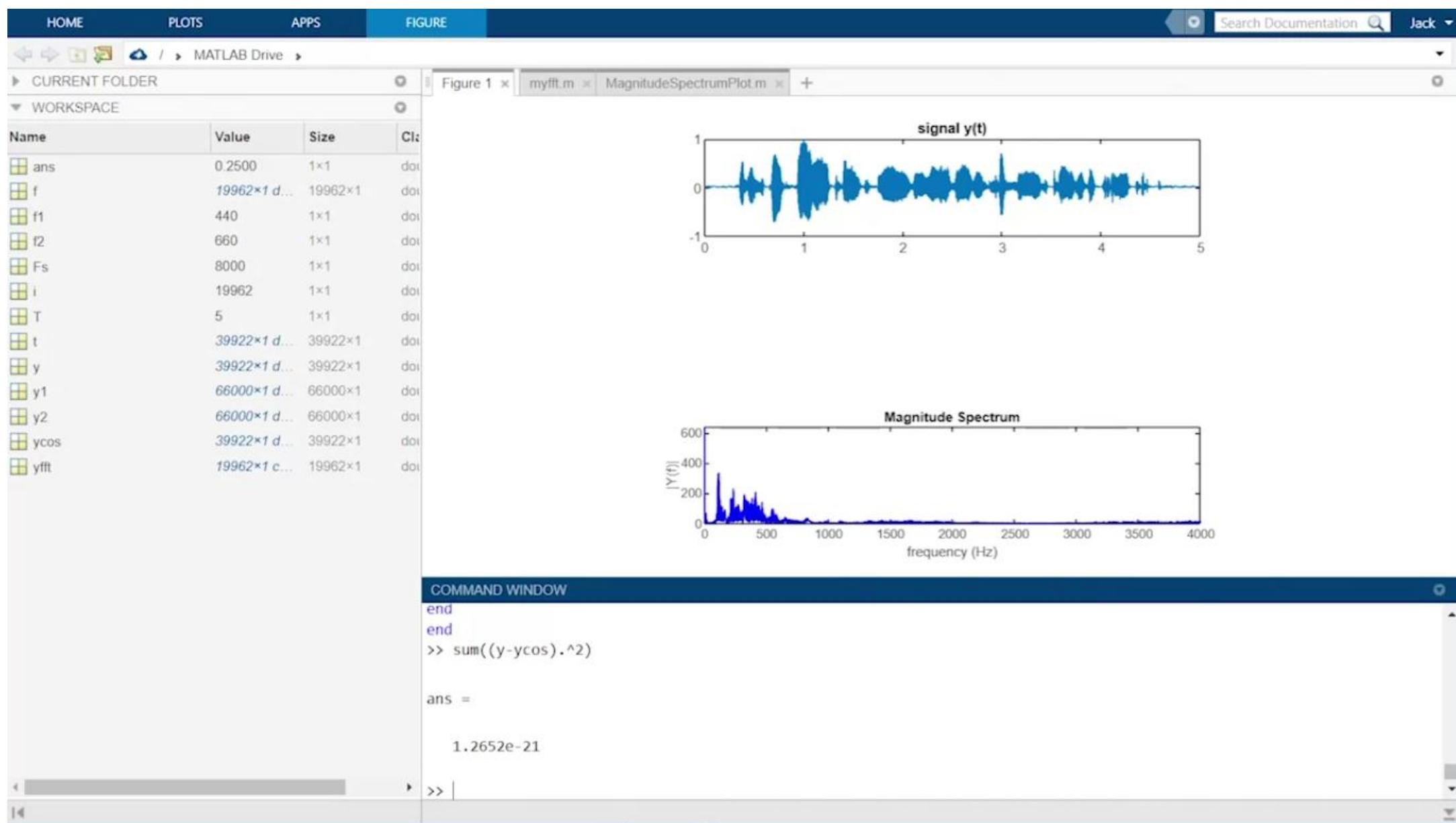


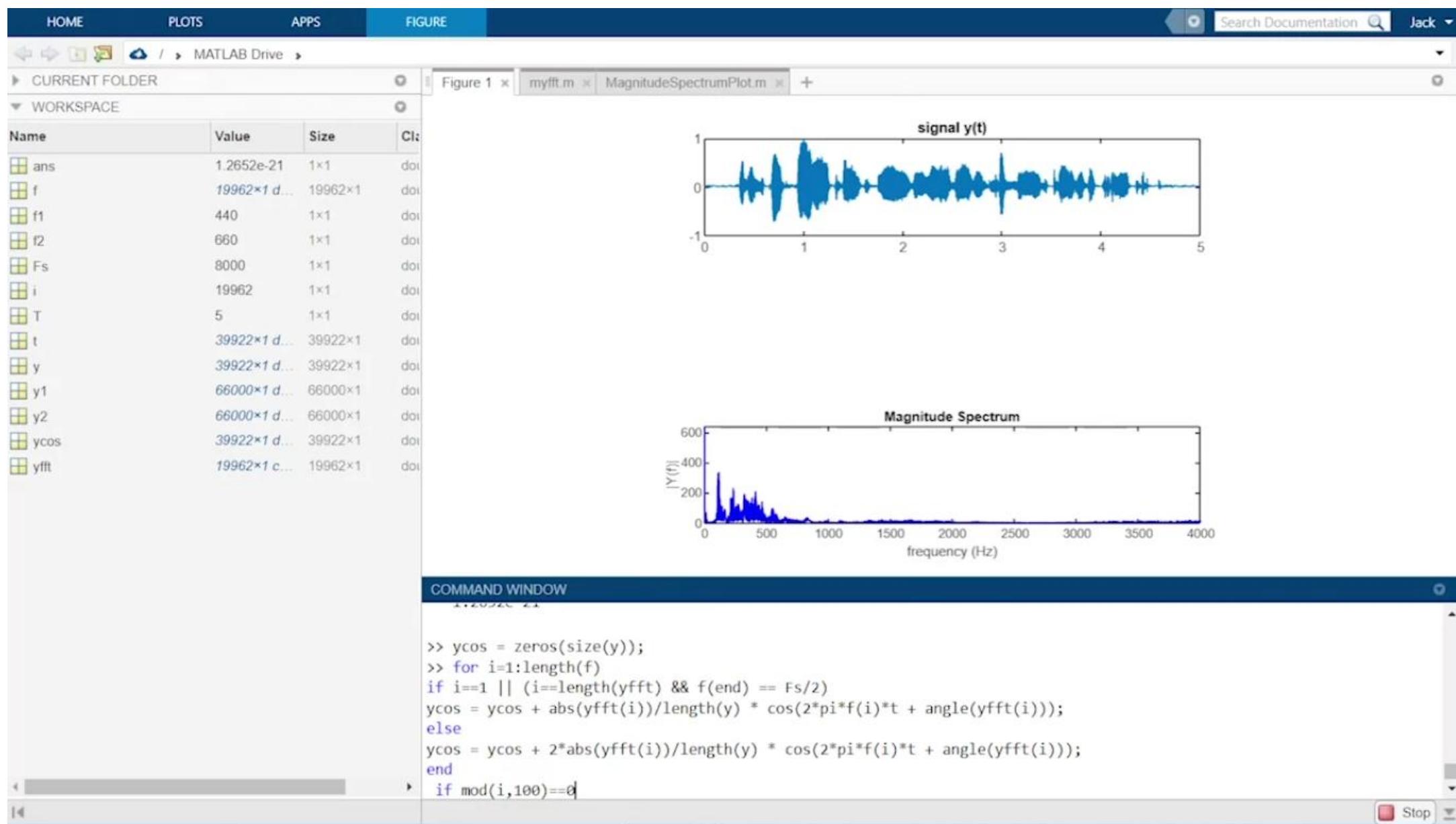


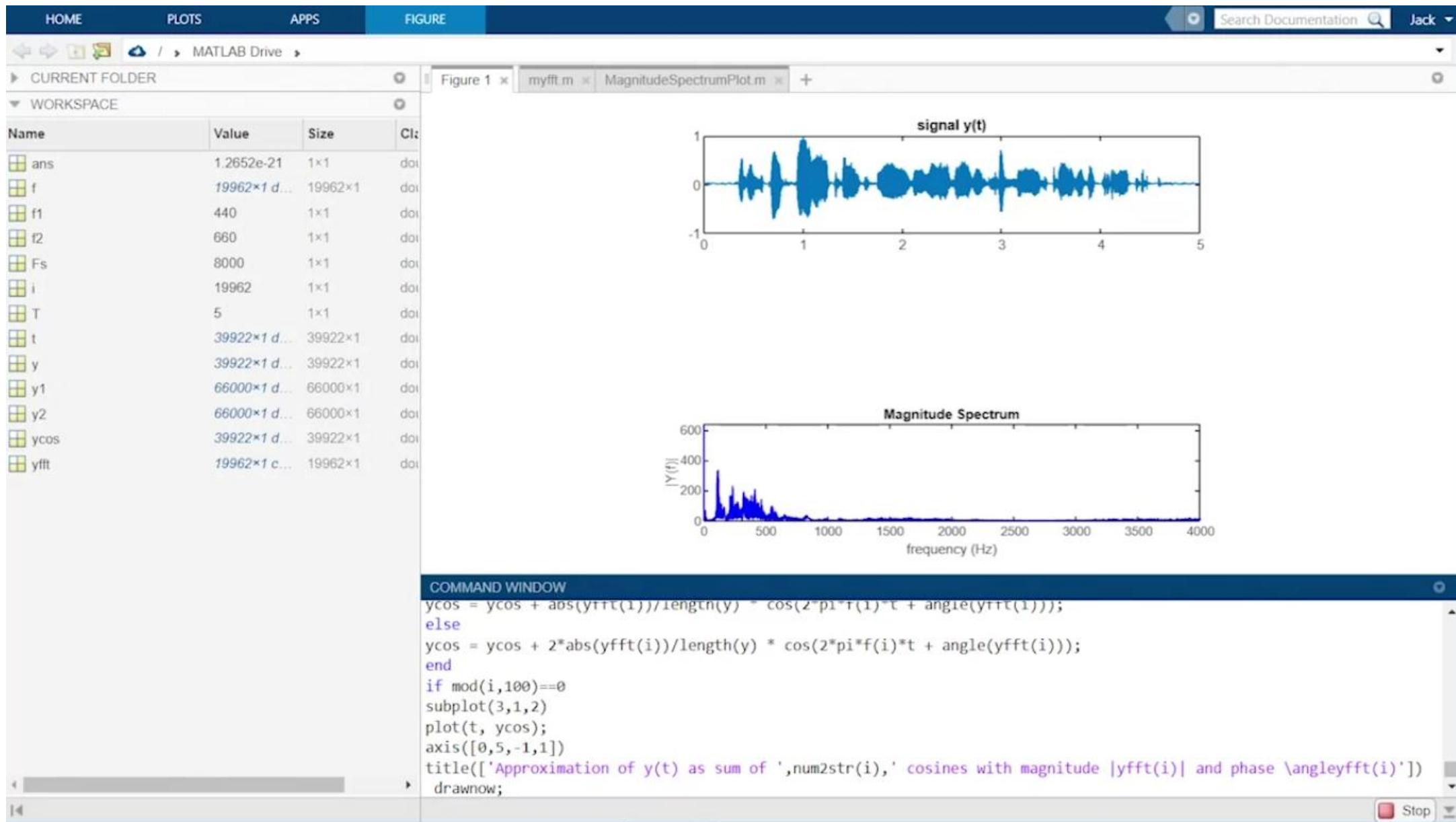




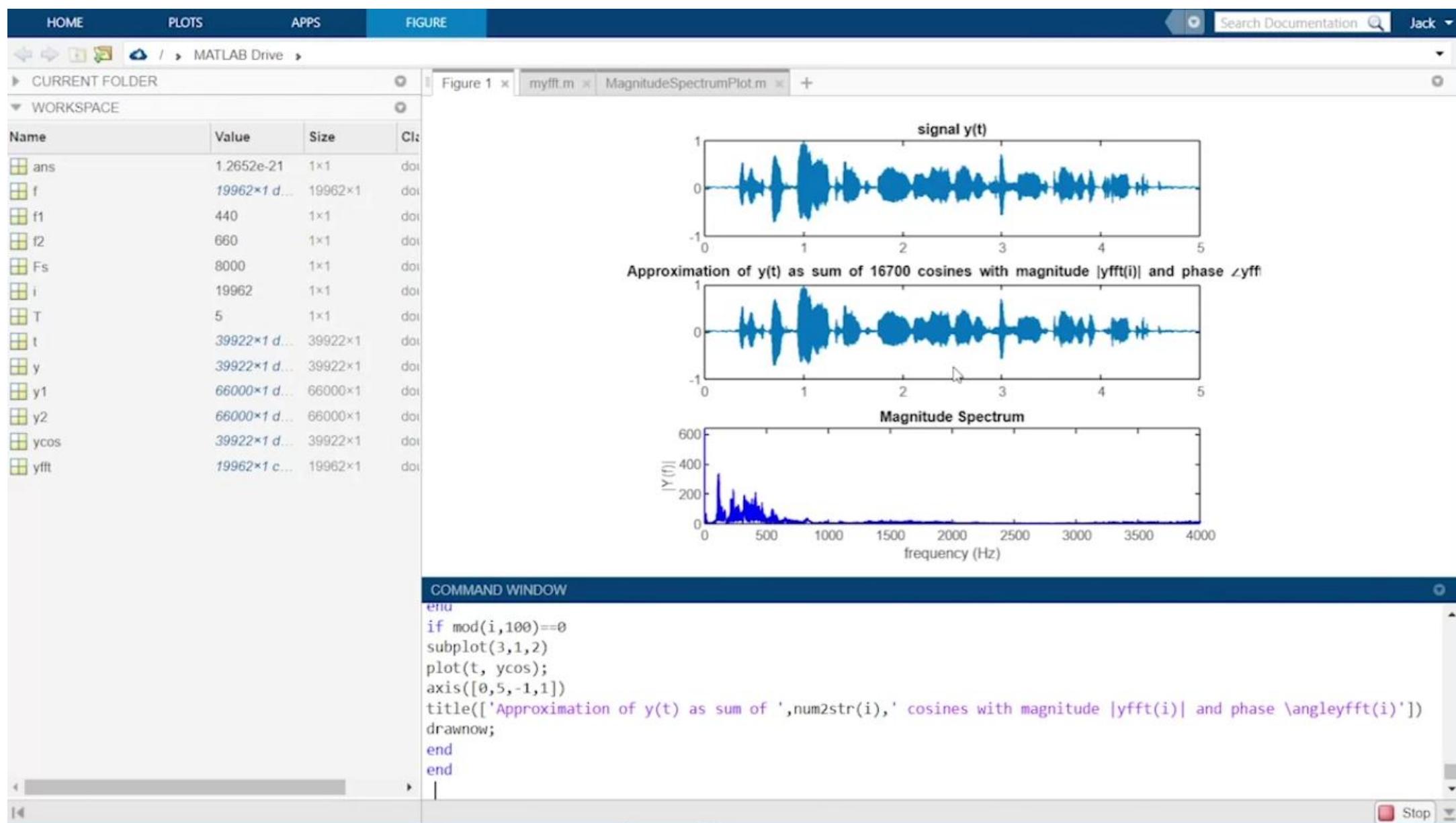






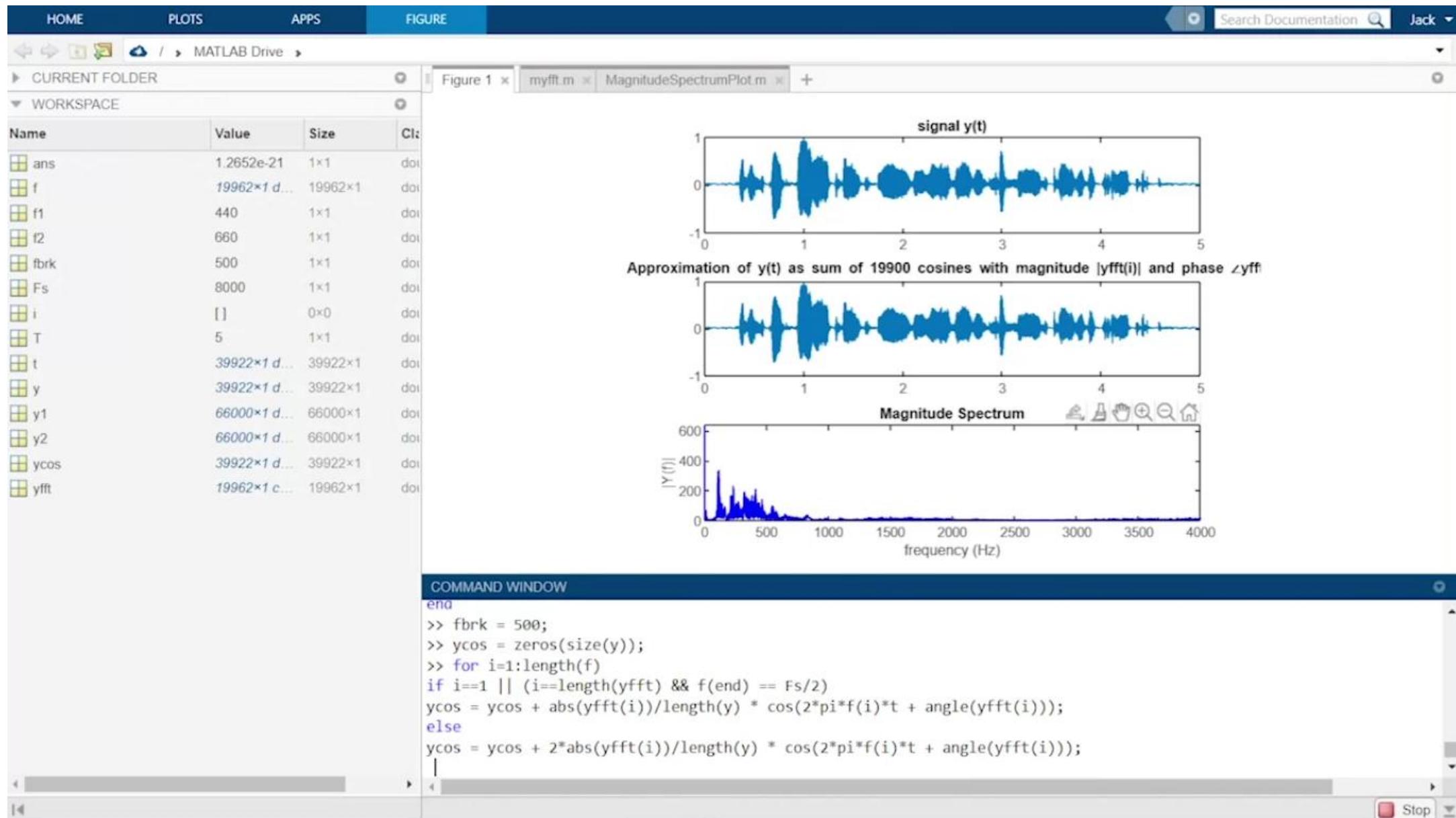


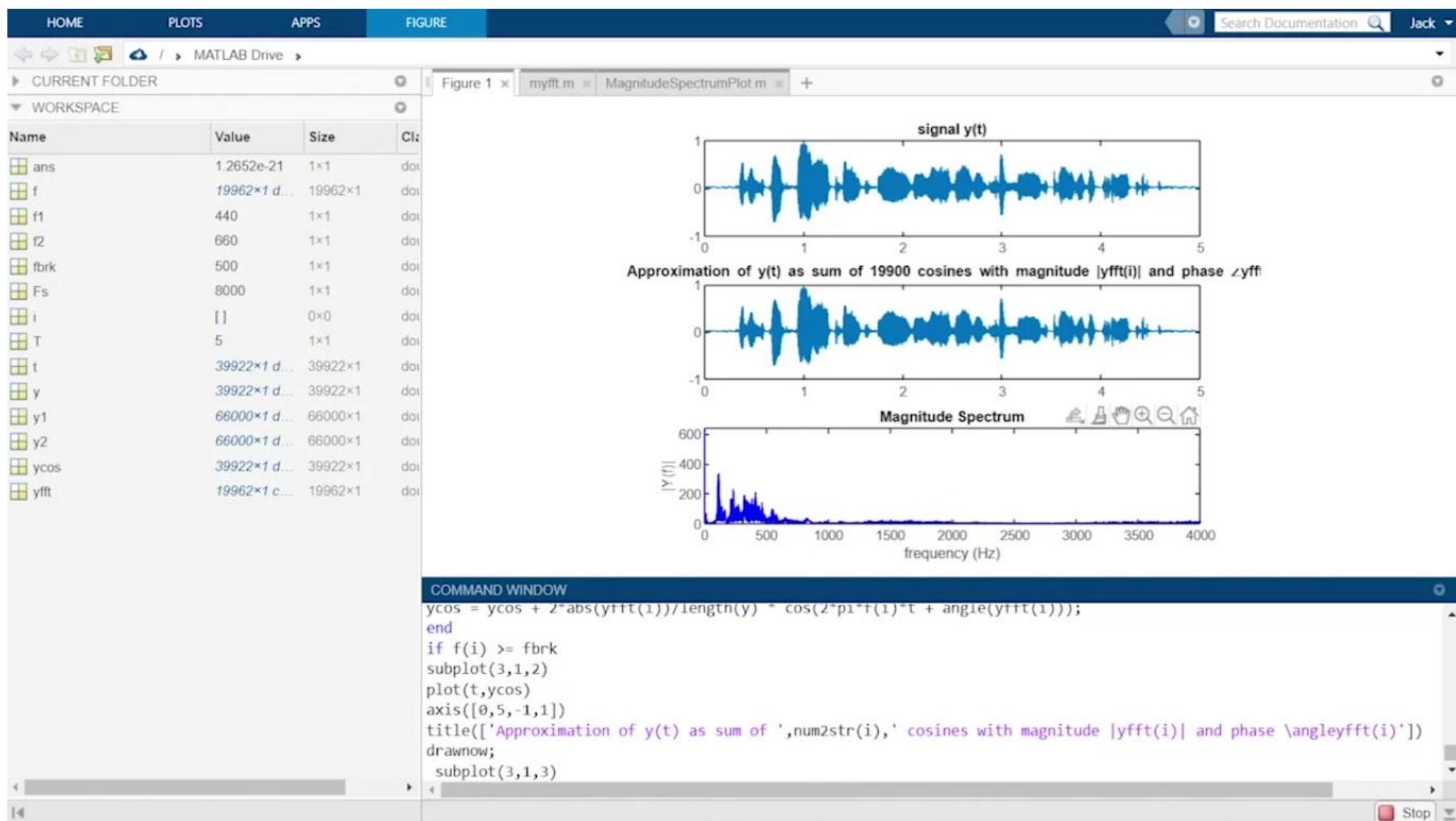


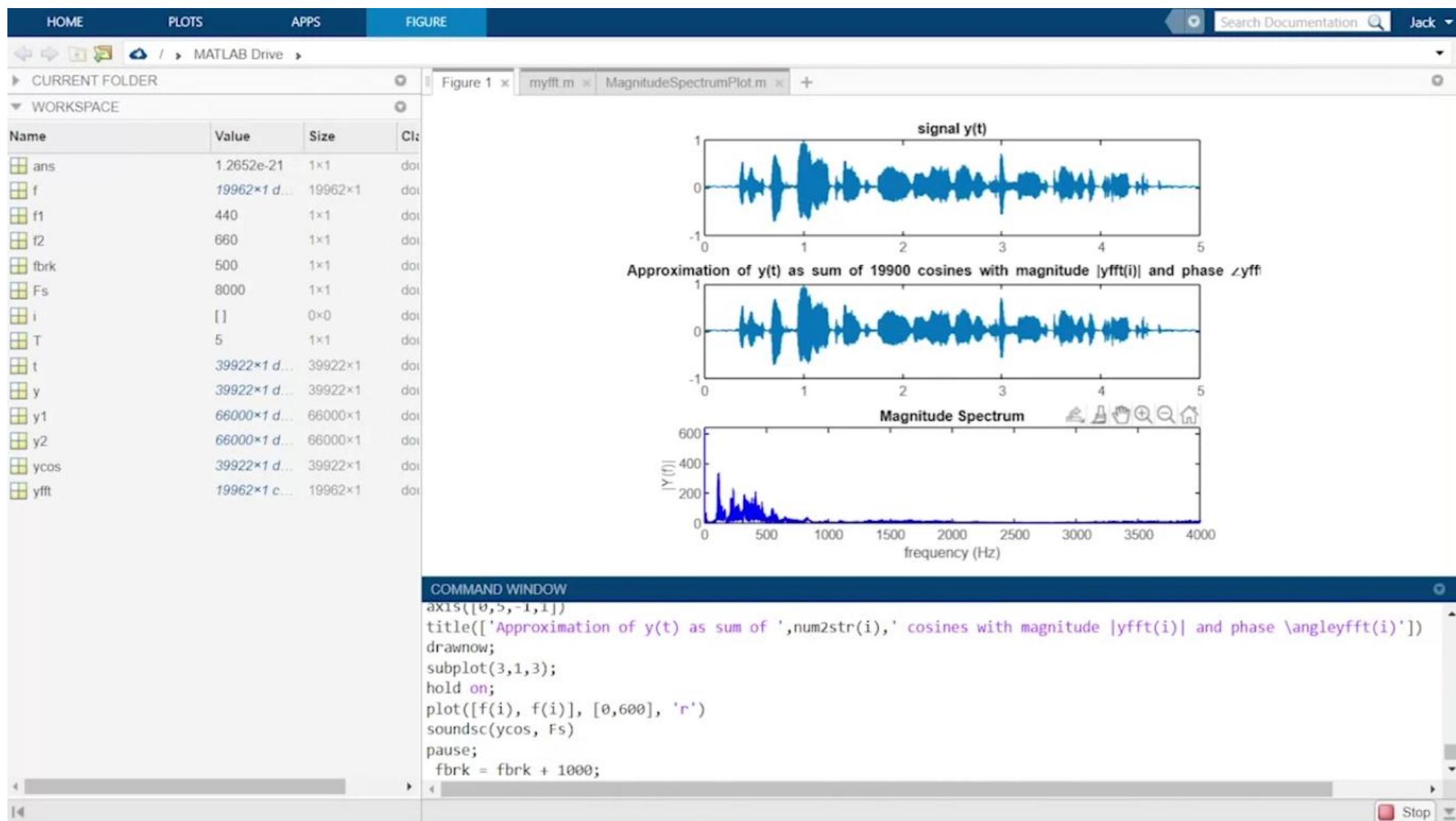


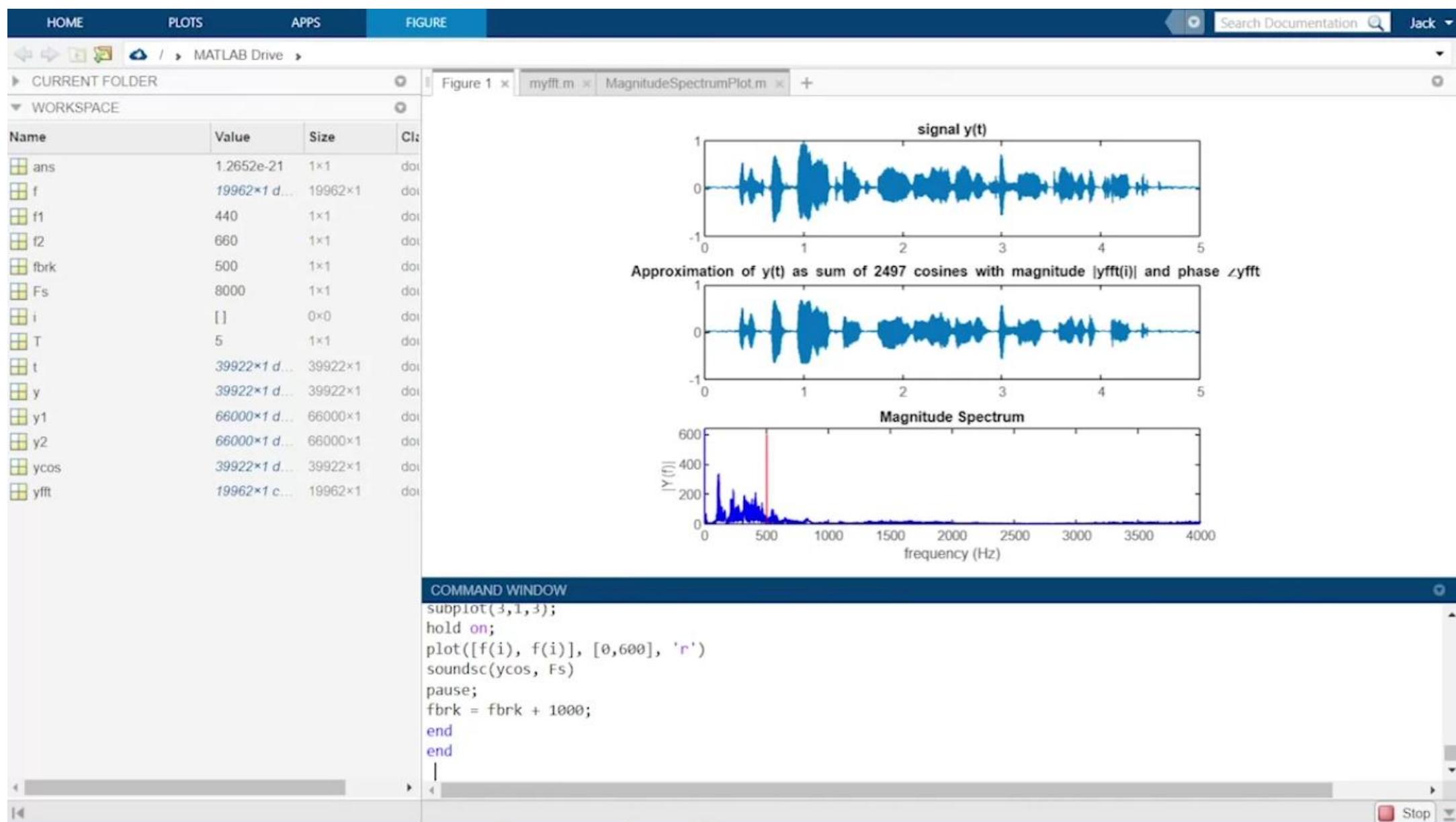












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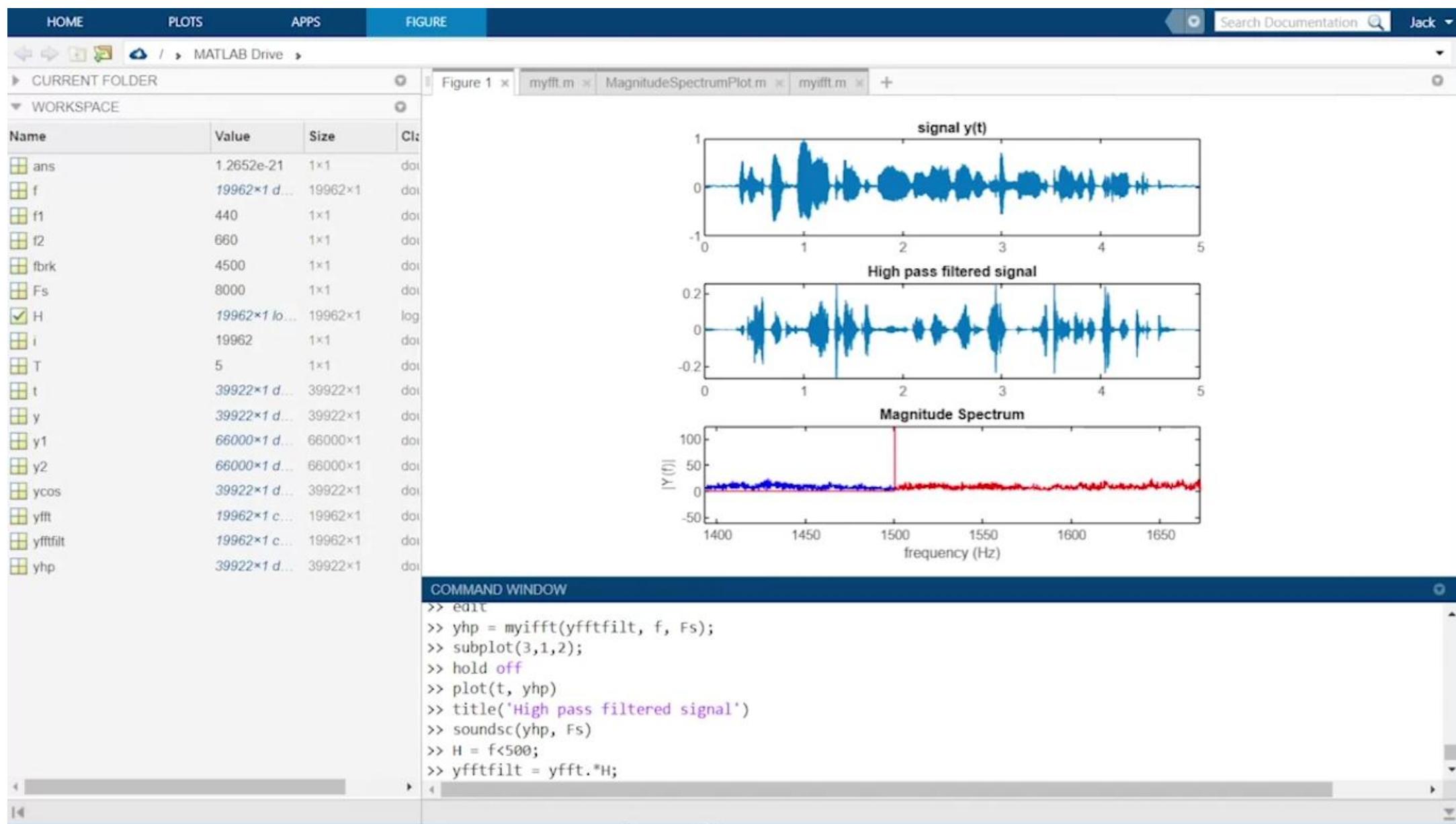
Name	Value	Size	Class
ans	1.2652e-21	1x1	double
f	19962x1 double	19962x1	double
f1	440	1x1	double
f2	660	1x1	double
fbrk	4500	1x1	double
Fs	8000	1x1	double
H	19962x1 logical	19962x1	logical
i	19962	1x1	double
T	5	1x1	double
t	39922x1 double	39922x1	double
y	39922x1 double	39922x1	double
y1	66000x1 double	66000x1	double
y2	66000x1 double	66000x1	double
ycos	39922x1 double	39922x1	double
yfft	19962x1 complex	19962x1	complex
yfftfilt	19962x1 complex	19962x1	complex

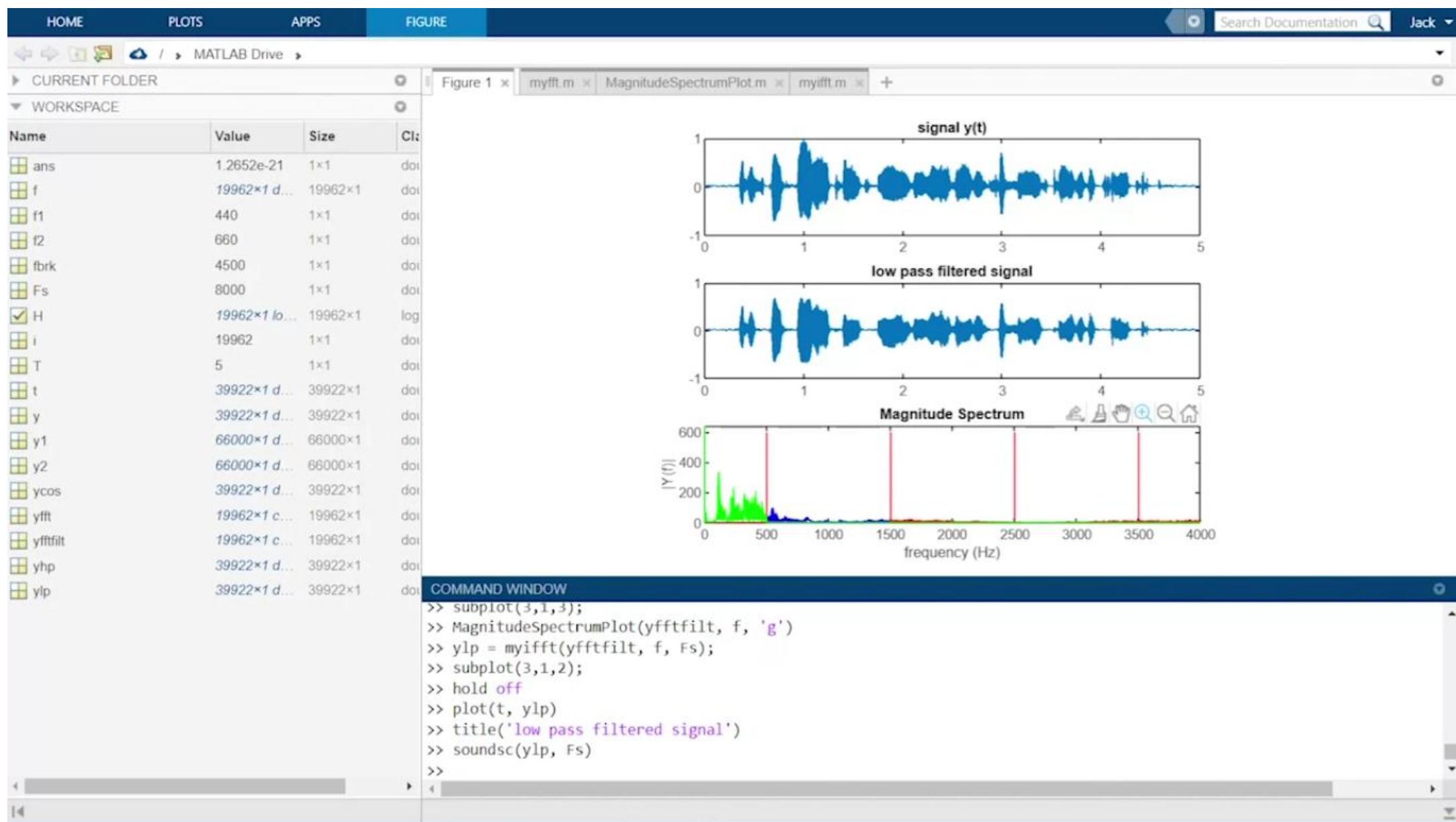
Figure 1 myfft.m MagnitudeSpectrumPlot.m myifft.m +

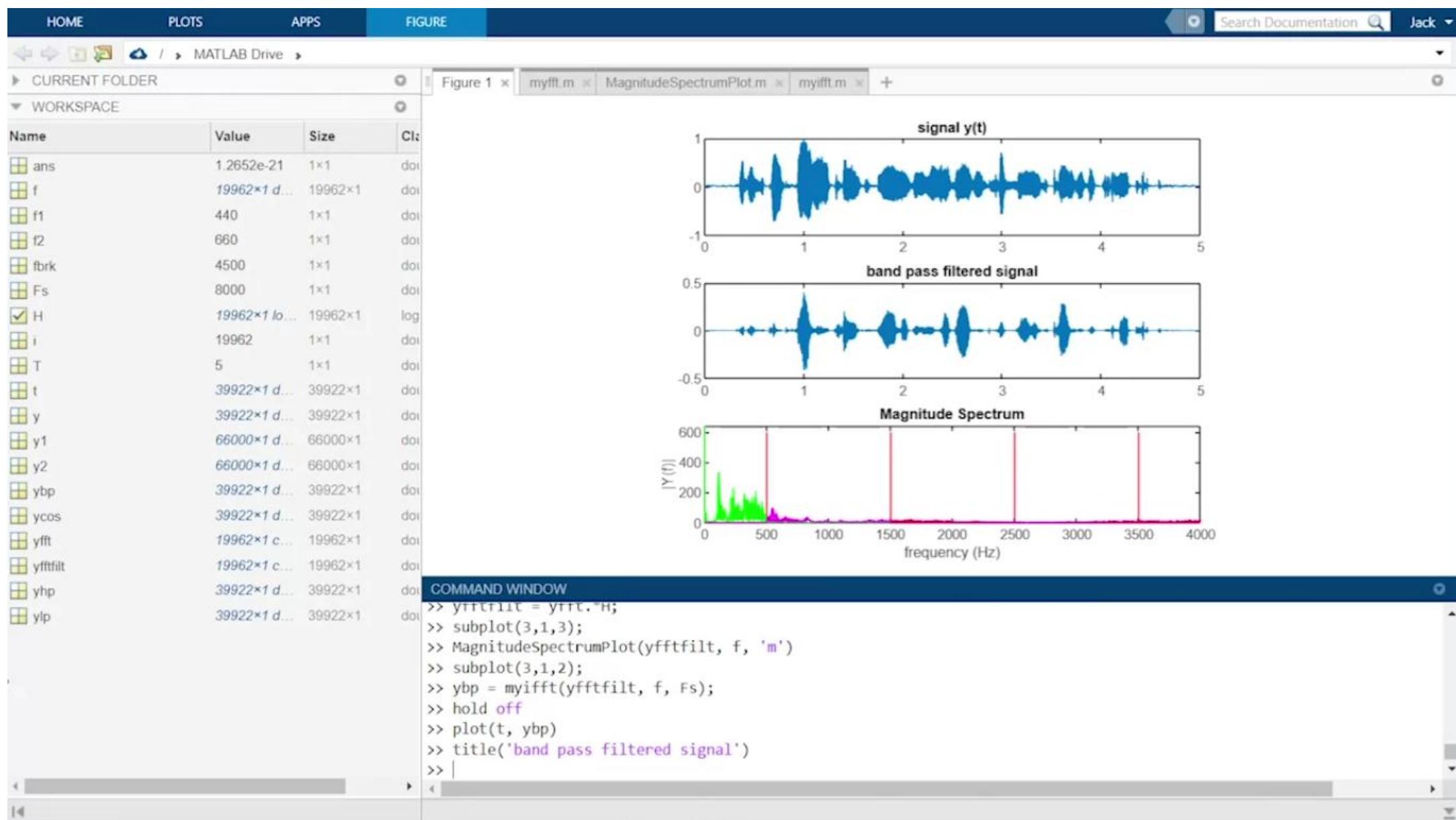
```
function y = myifft(yfft, f, Fs)
    if f(end)==Fs/2
        y = ifft([yfft; conj(flipud(yfft(2:end-1)))]);
    else
        y = ifft([yfft; conj(flipud(yfft(2:end)))]);
    end
end
```

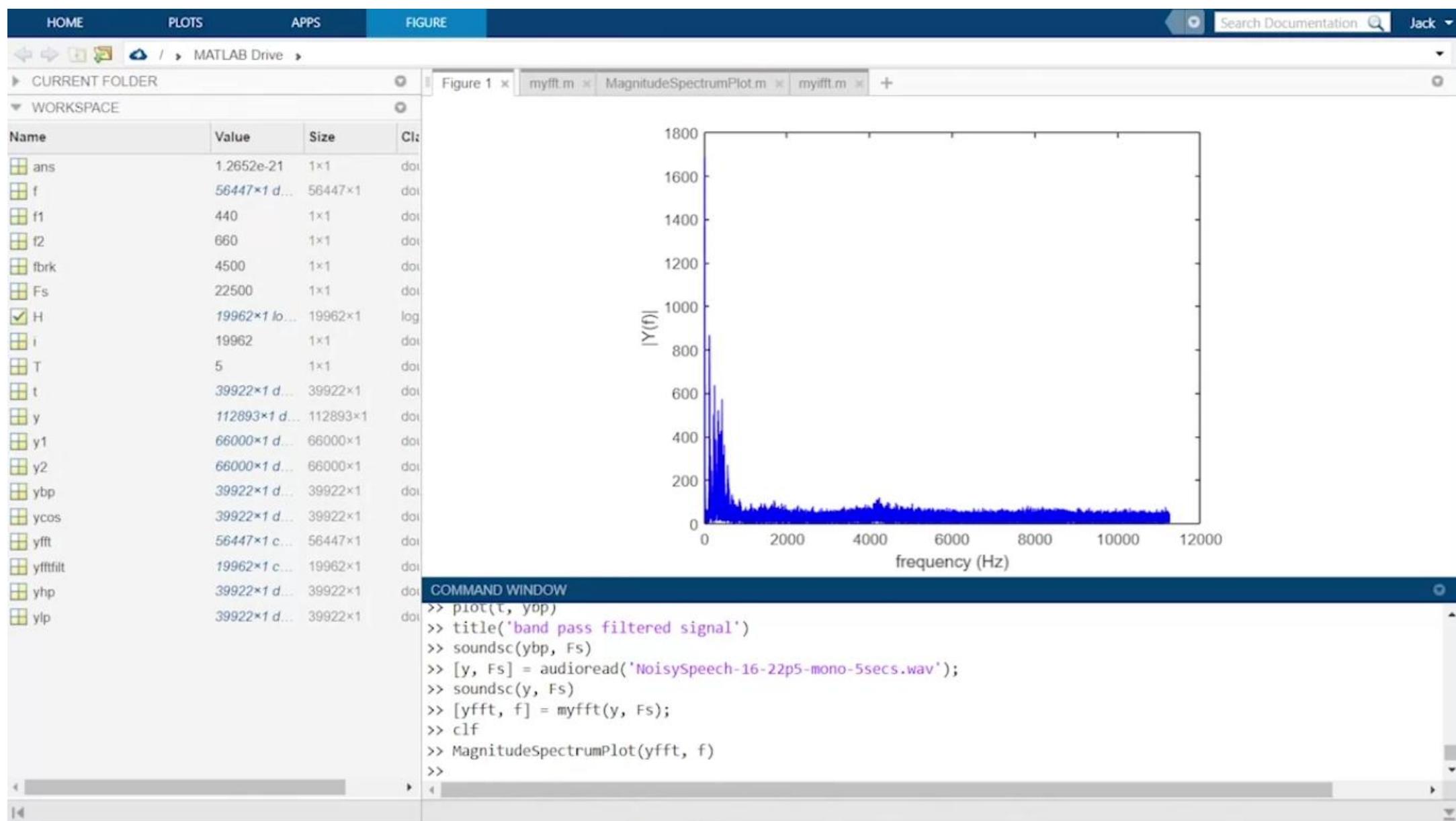
COMMAND WINDOW

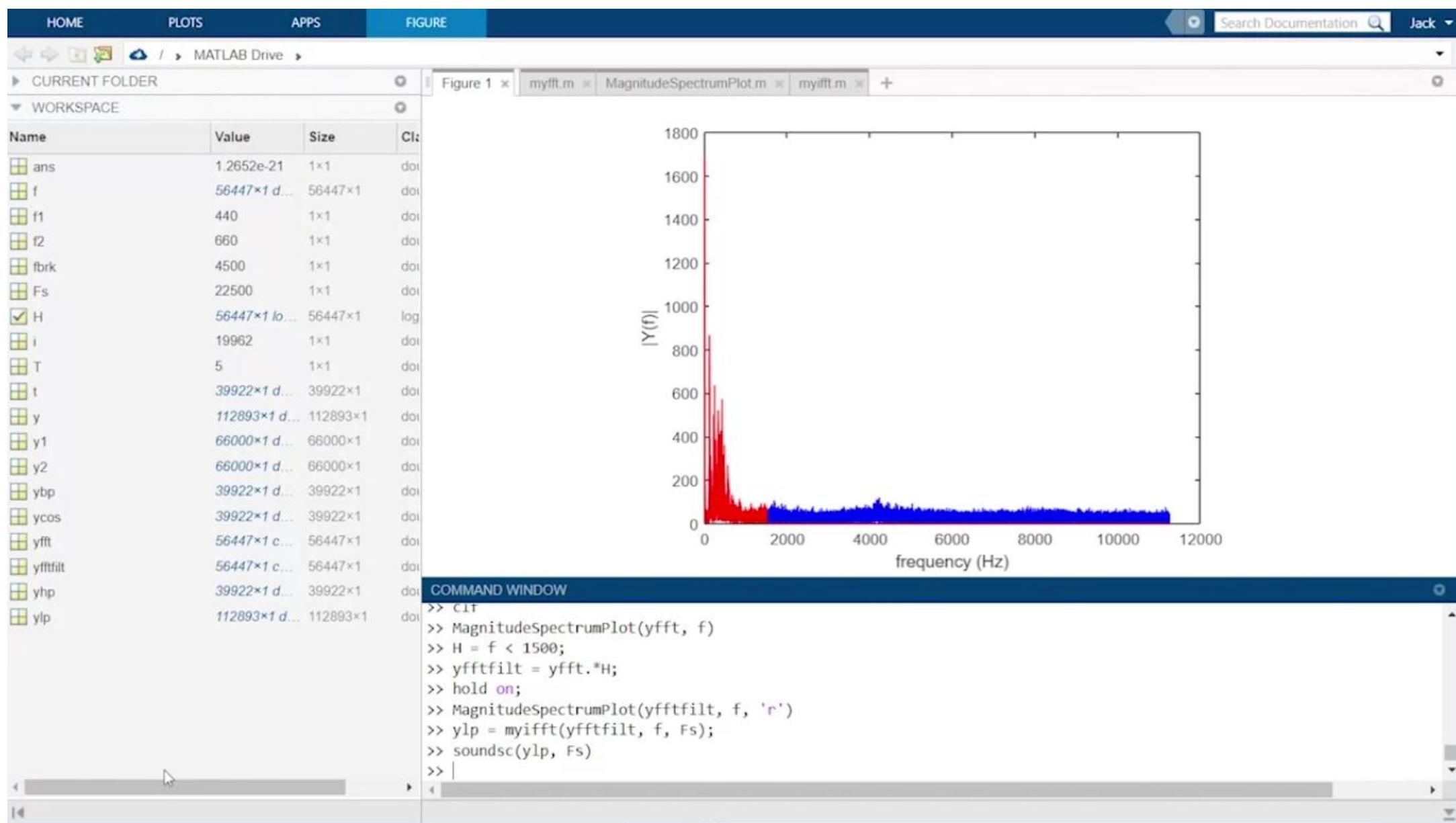
```
pause;
fbrk = fbrk + 1000;
end
end
>> H = f>1500;
>> yfftfilt = yfft.*H;
>> MagnitudeSpectrumPlot(yfftfilt, f, 'r')
>> edit
>>
```

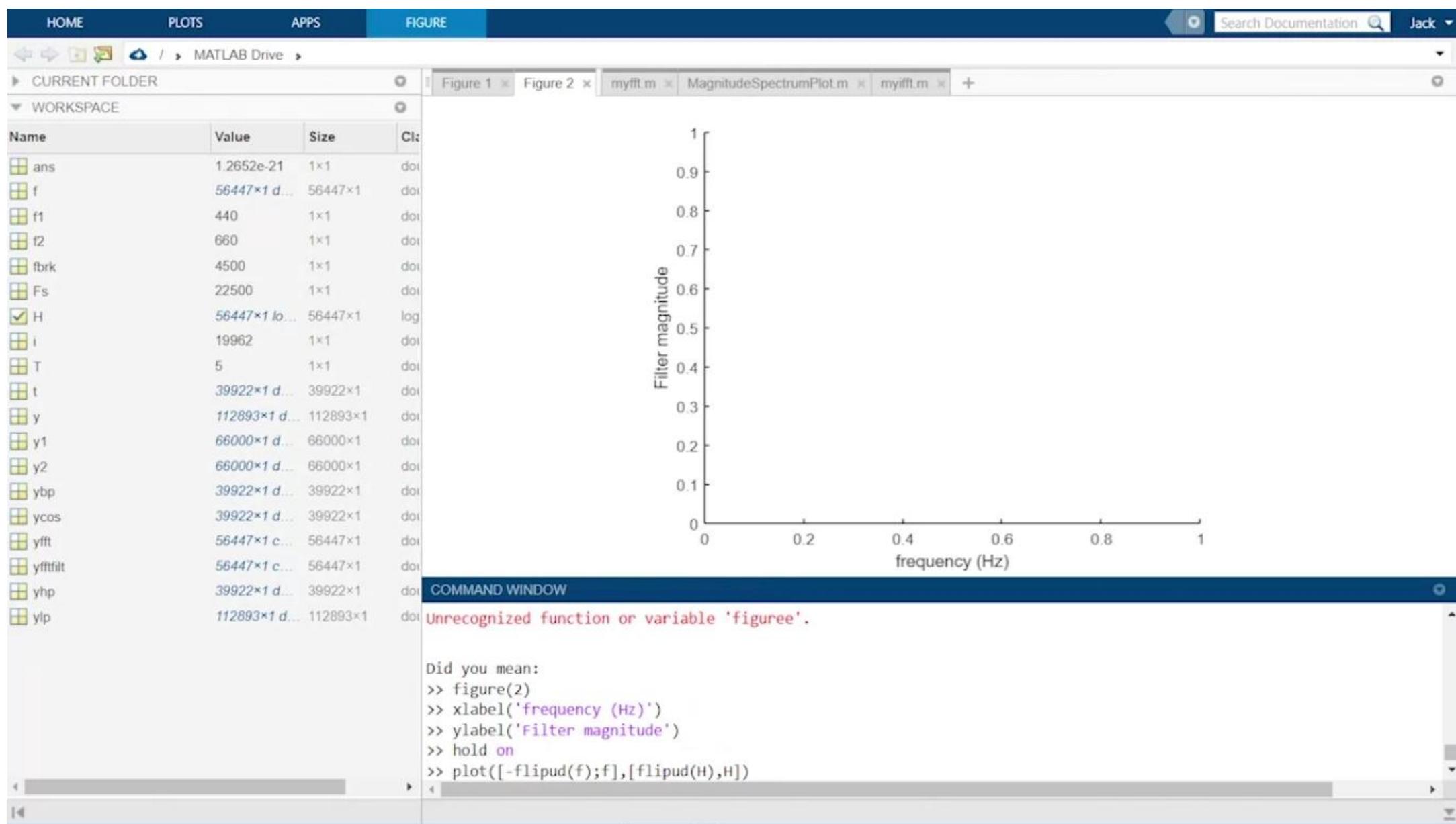


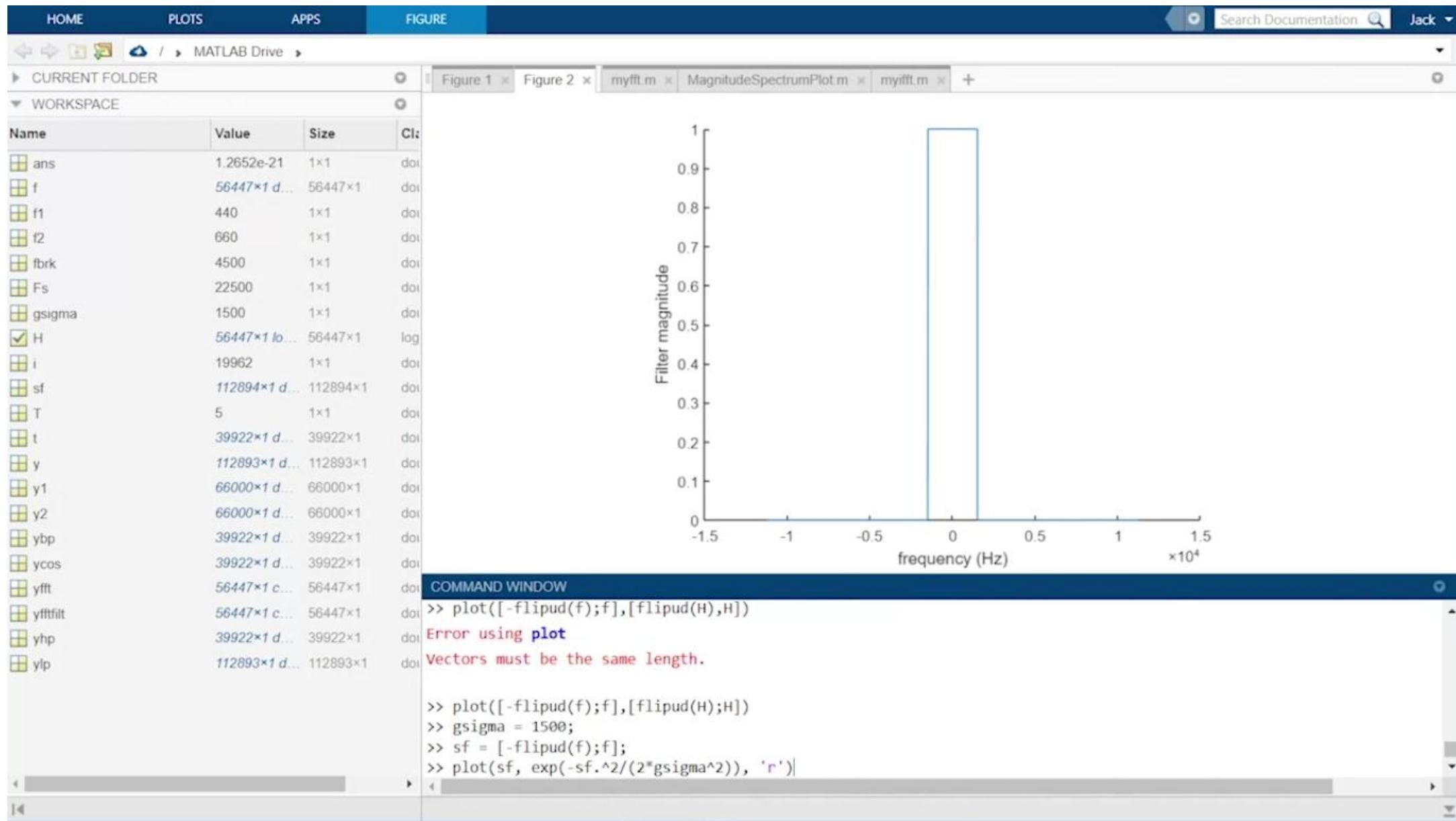


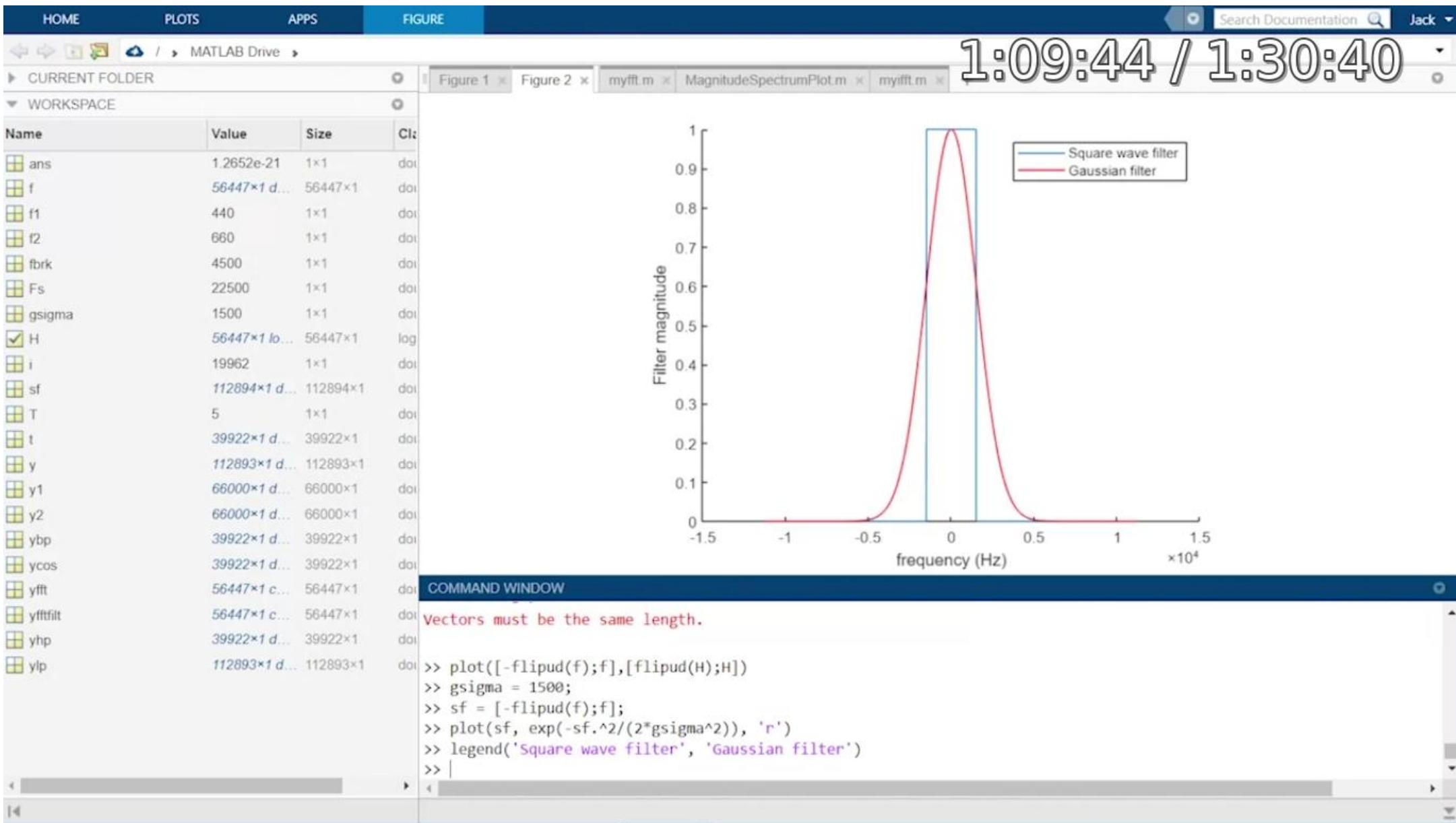


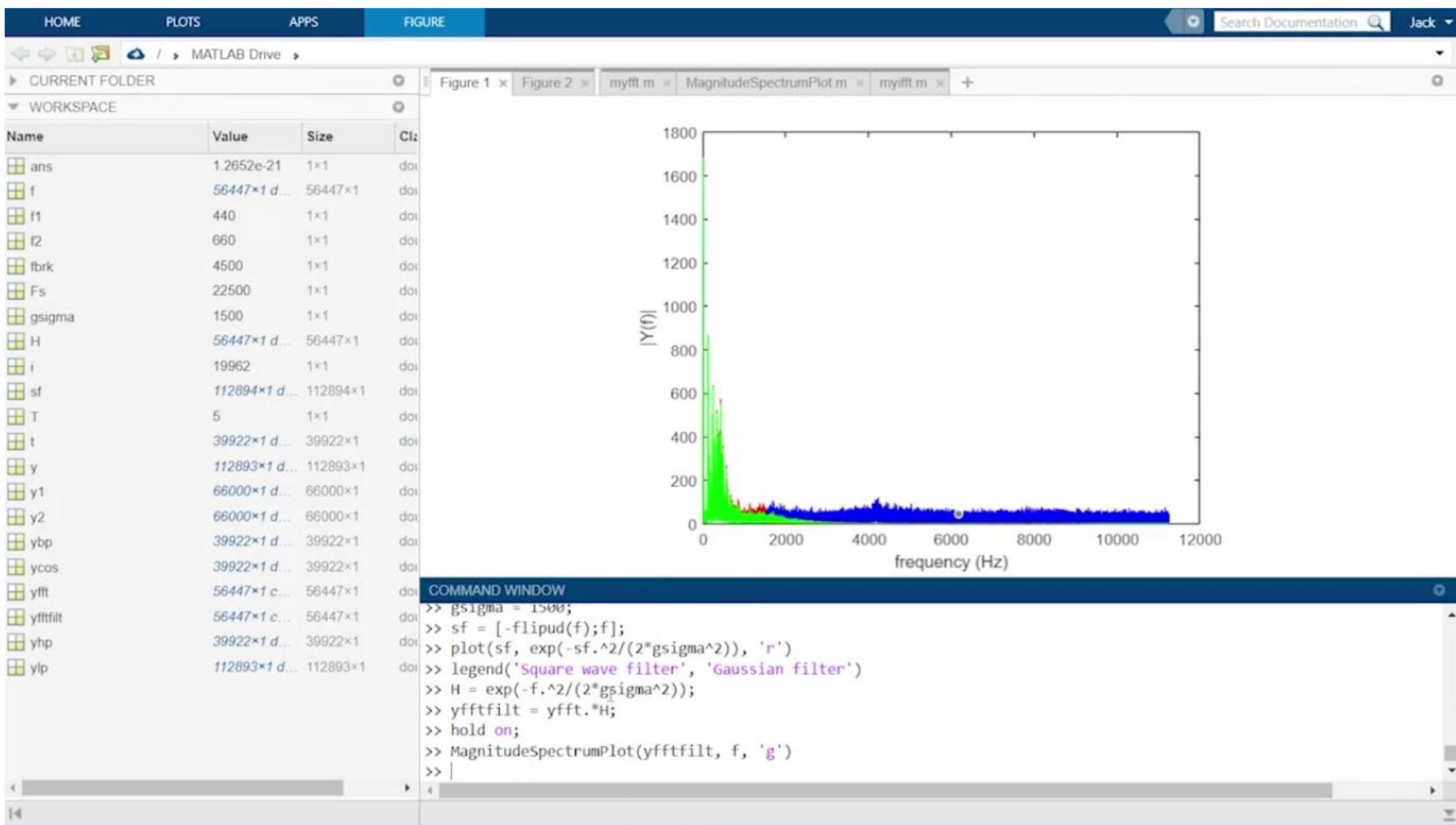


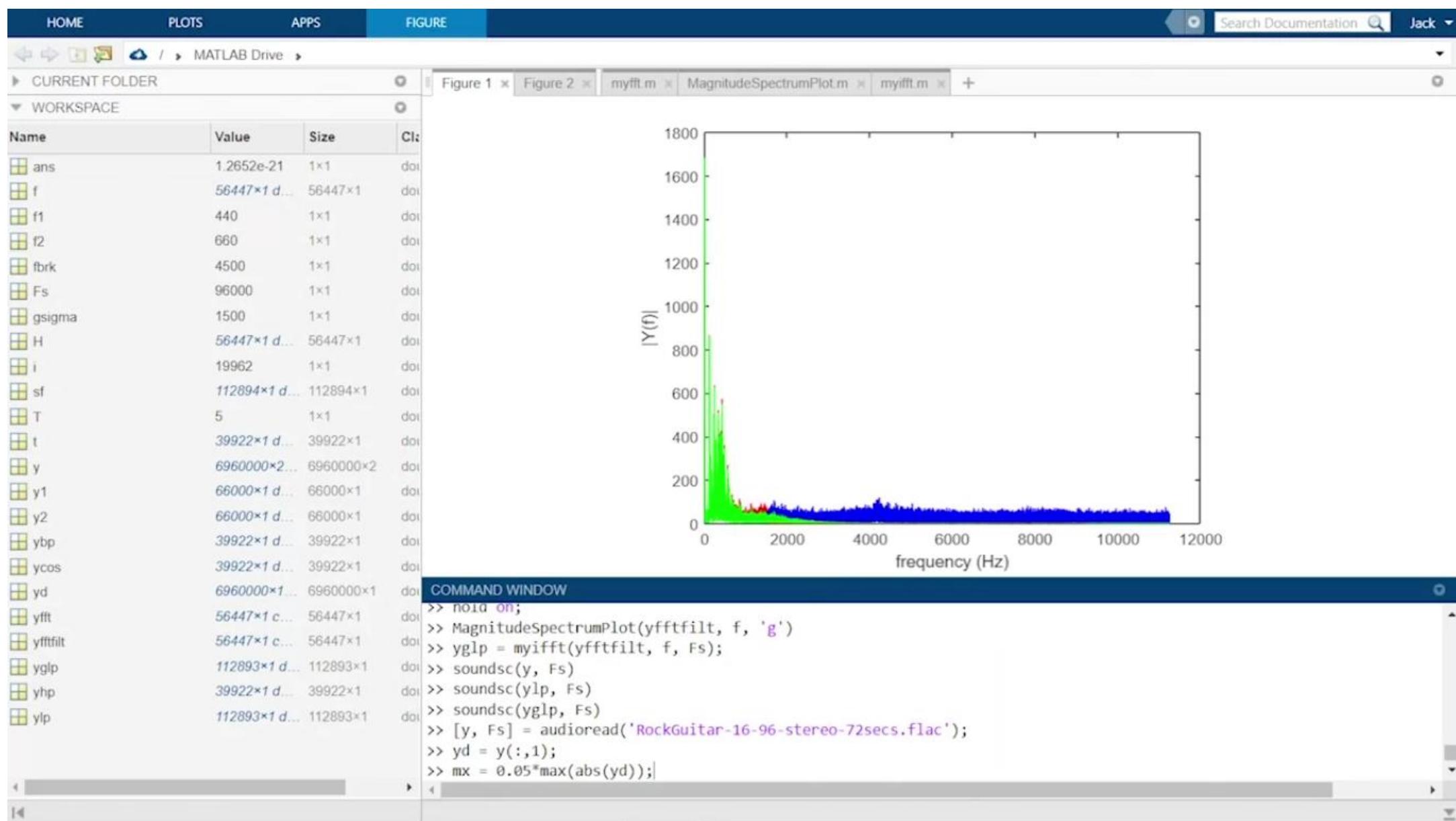












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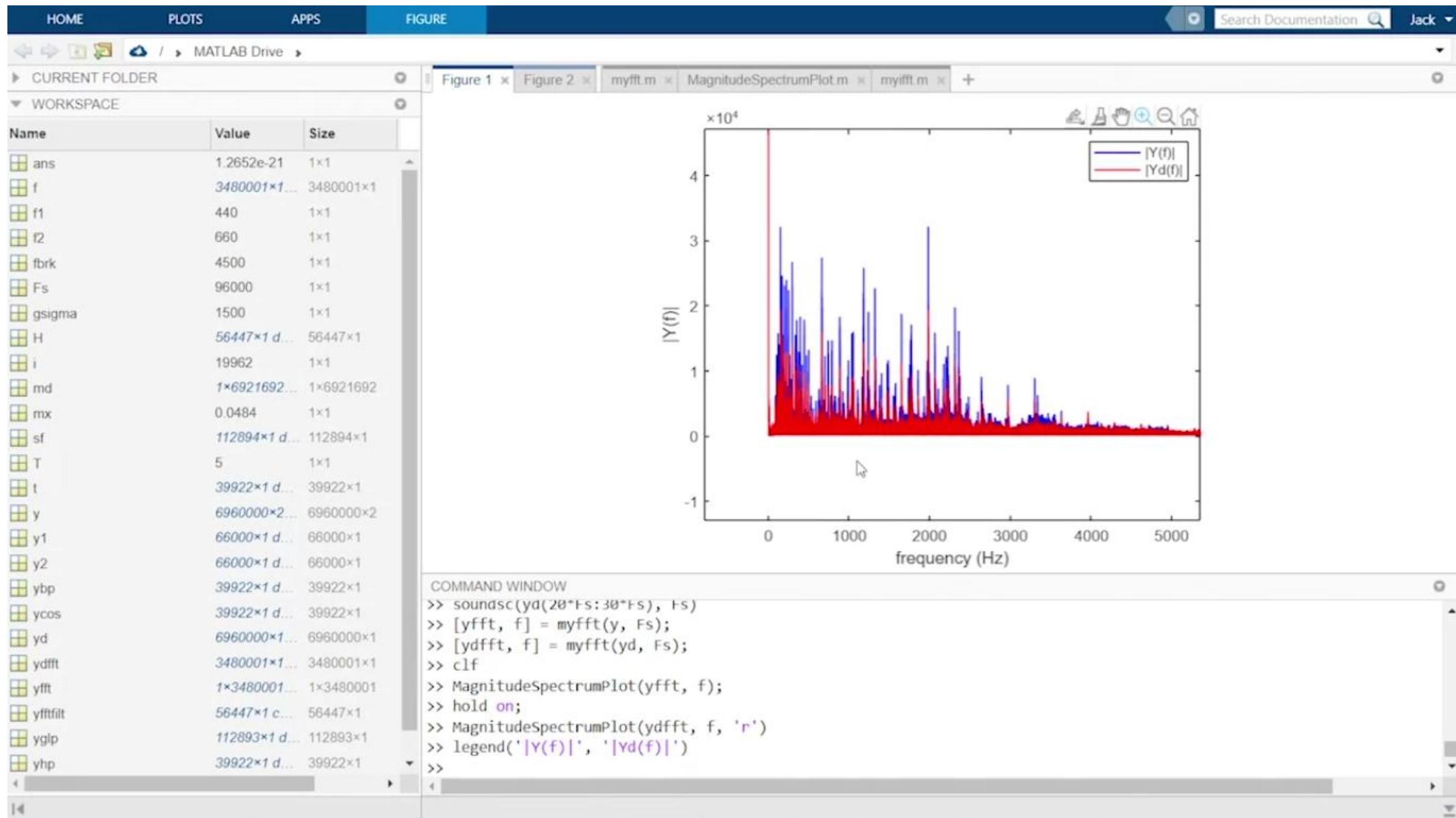
Name	Value	Size
ans	1.2652e-21	1x1
f	3480001x1...	3480001x1
f1	440	1x1
f2	660	1x1
fbrk	4500	1x1
Fs	96000	1x1
gsigma	1500	1x1
H	56447x1 d...	56447x1
i	19962	1x1
md	1x6921692...	1x6921692
mx	0.0484	1x1
sf	112894x1 d...	112894x1
T	5	1x1
t	39922x1 d...	39922x1
y	6960000x2...	6960000x2
y1	66000x1 d...	66000x1
y2	66000x1 d...	66000x1
ybp	39922x1 d...	39922x1
ycos	39922x1 d...	39922x1
yd	6960000x1...	6960000x1
ydffft	3480001x1...	3480001x1
yfft	1x3480001...	1x3480001
yfftfilt	56447x1 c...	56447x1
yglp	112893x1 d...	112893x1
yhp	39922x1 d...	39922x1

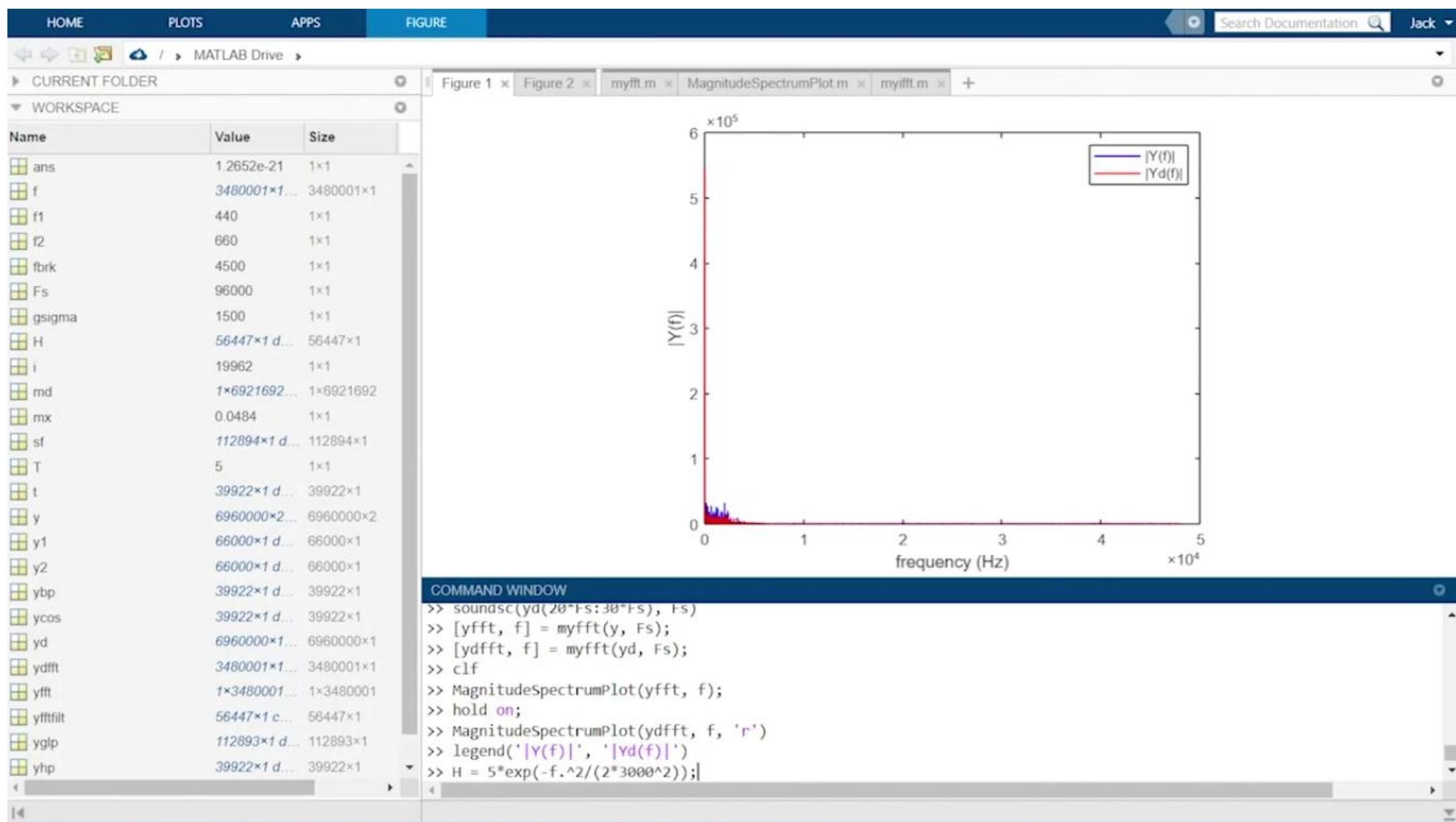
Figure 1 x Figure 2 x myfft.m x MagnitudeSpectrumPlot.m x myifft.m x +

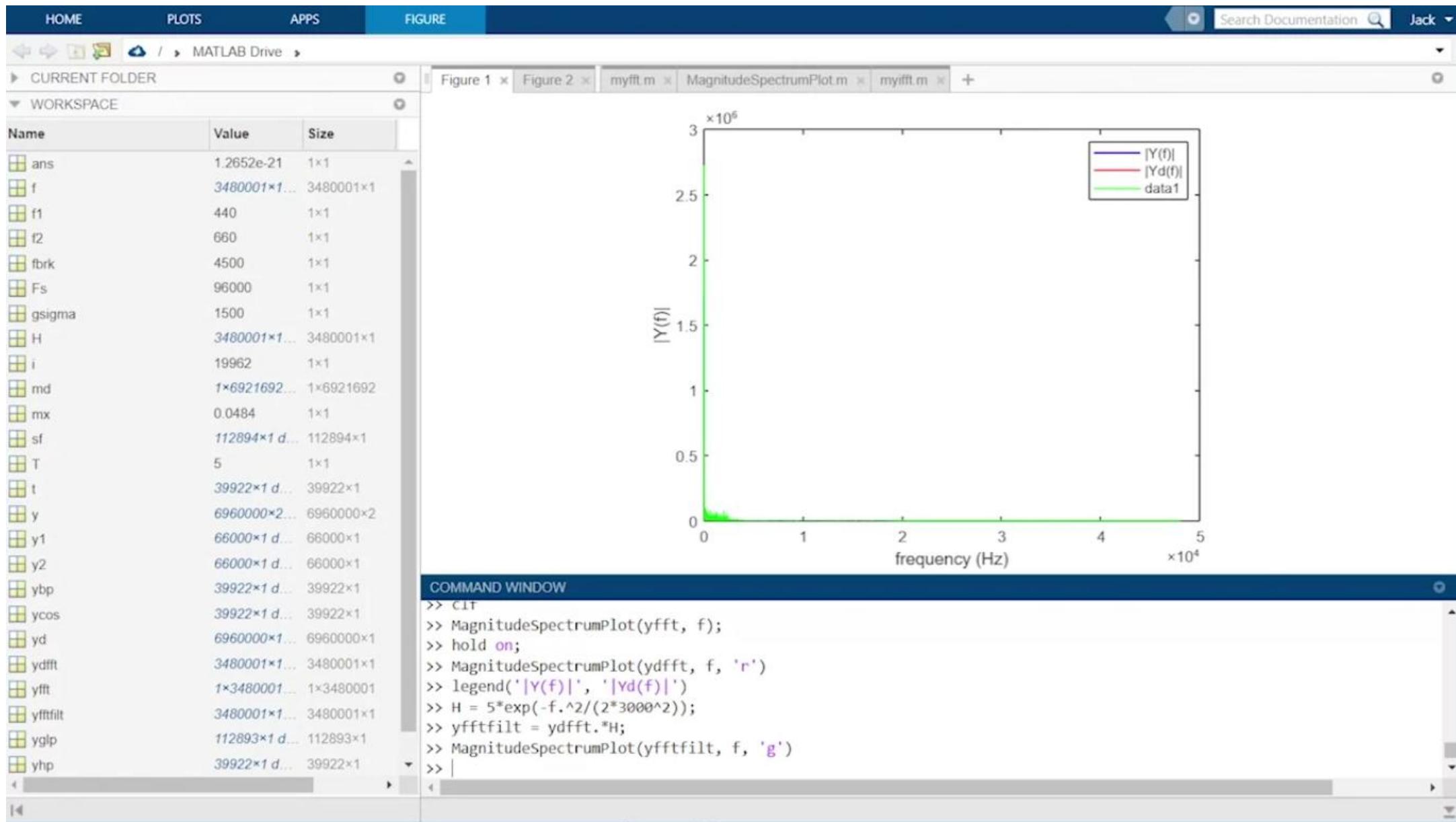
COMMAND WINDOW

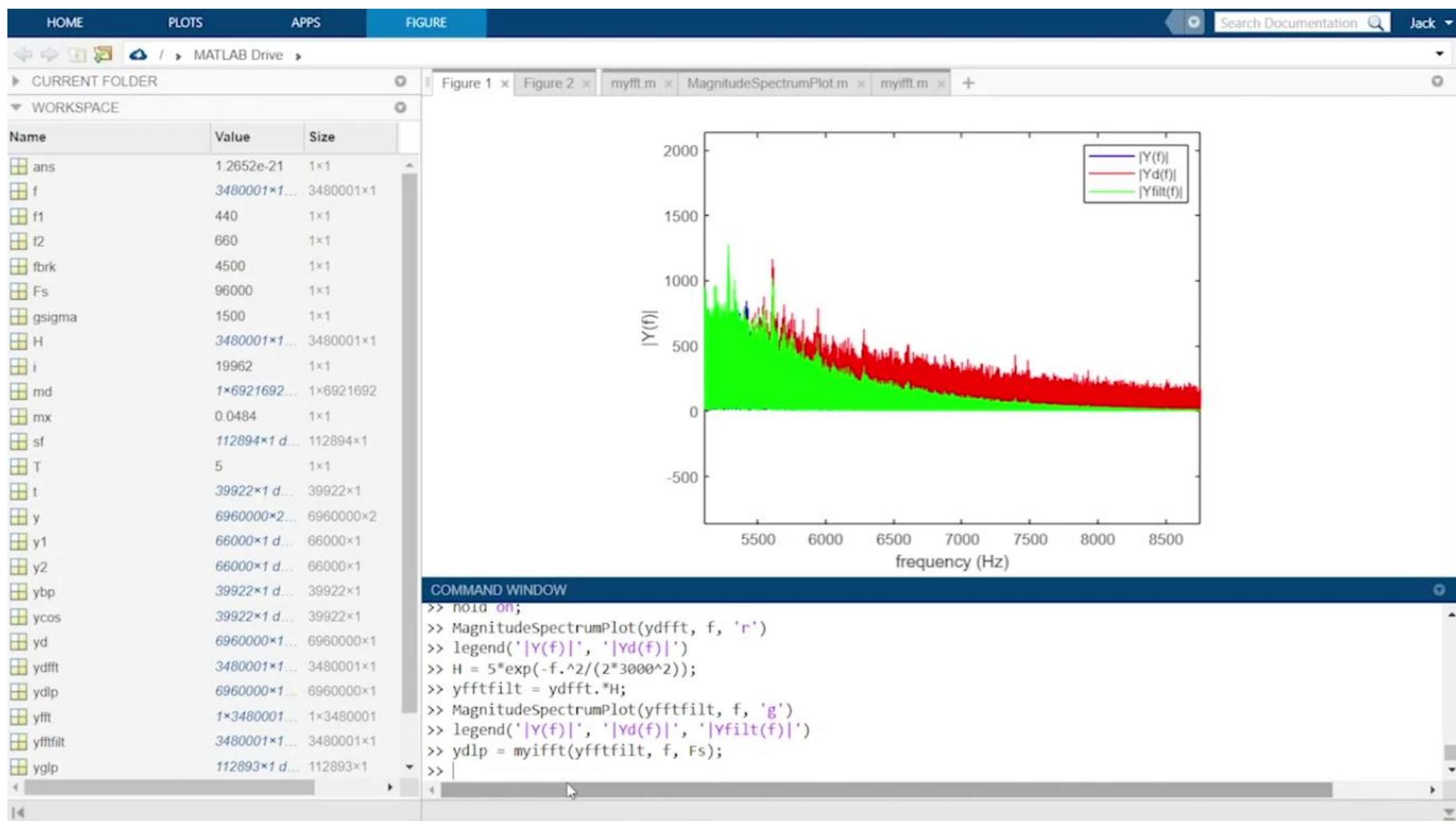
```
>> mx = 0.05*max(abs(yd));
>> yd(yd>mx) = mx;
>> md(yd<-mx) = -mx;
>> soundsc(yd(20*Fs:30*Fs), Fs)
>> [yfft, f] = myfft(y, Fs);
>> [ydffft, f] = myfft(yd, Fs);
>> clf
>> MagnitudeSpectrumPlot(yfft, f);
```

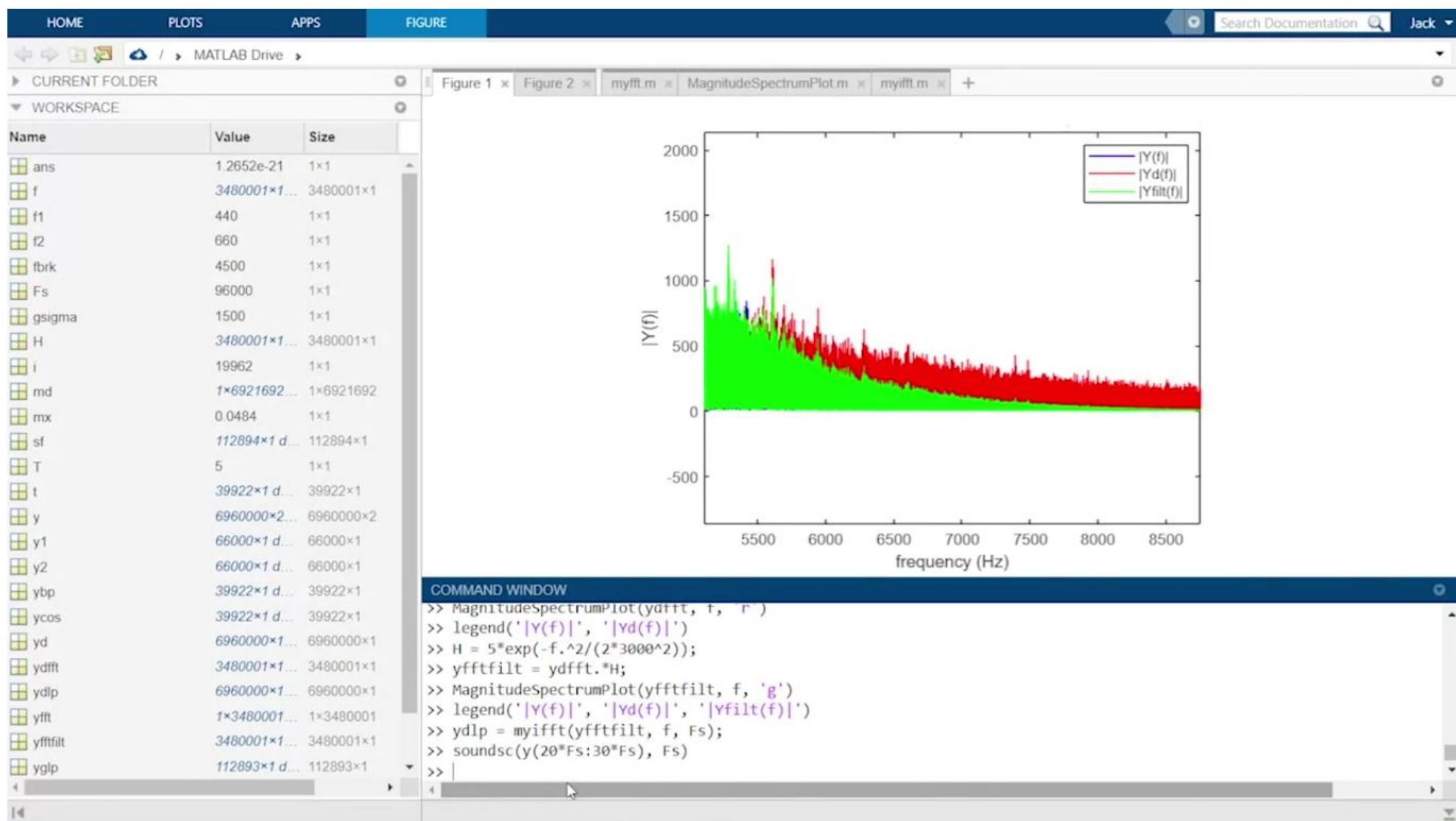
Busy

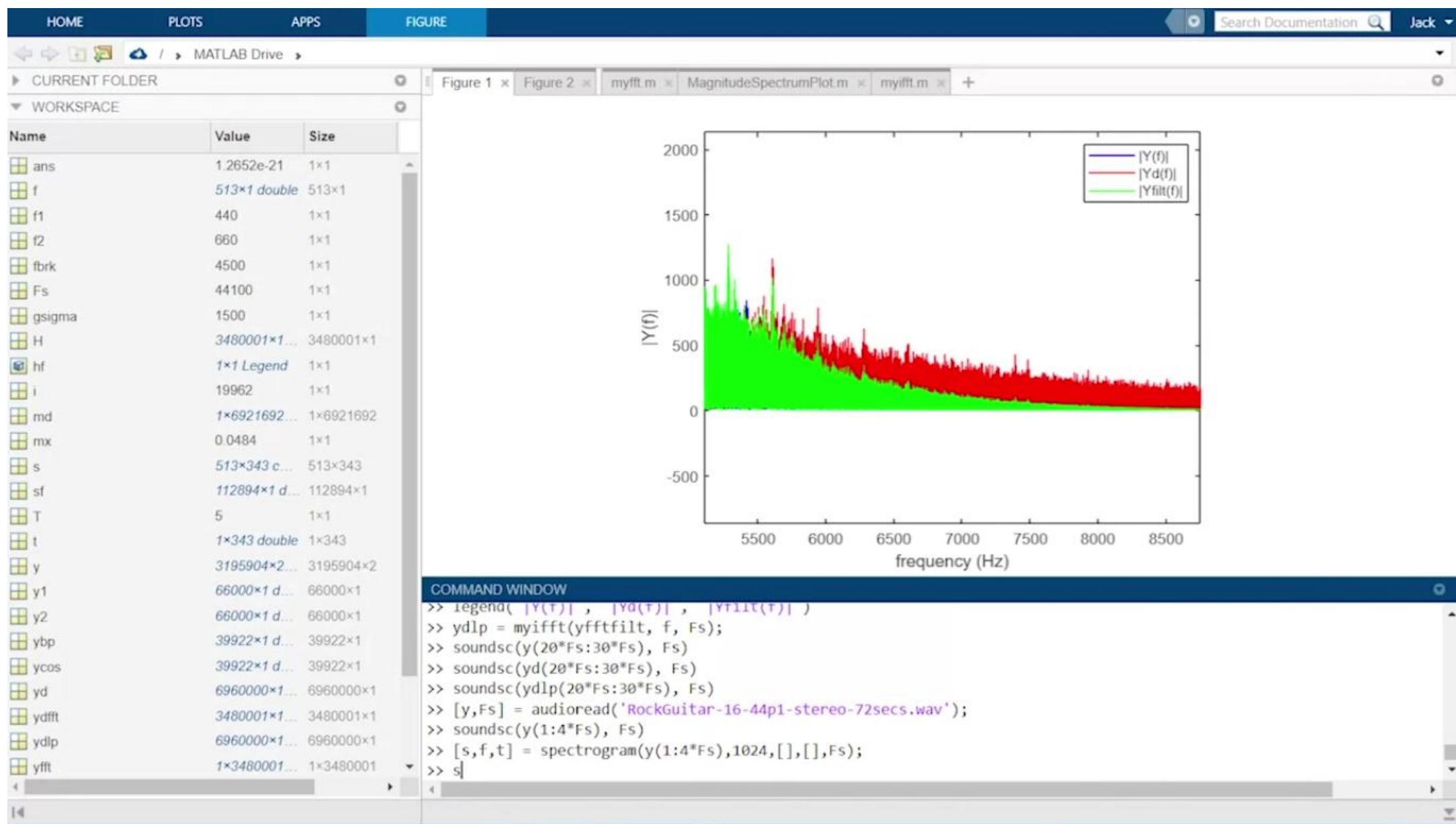


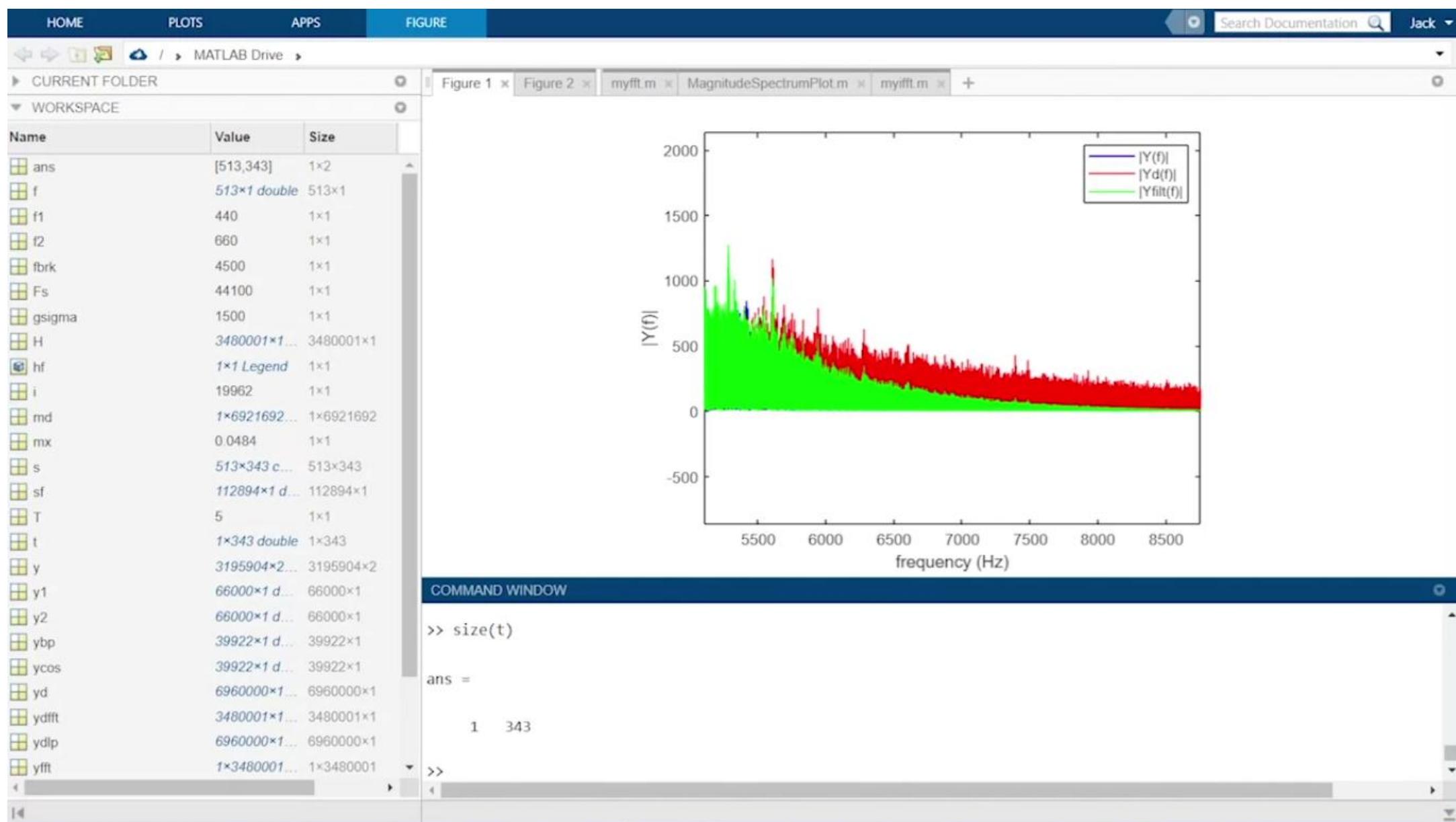


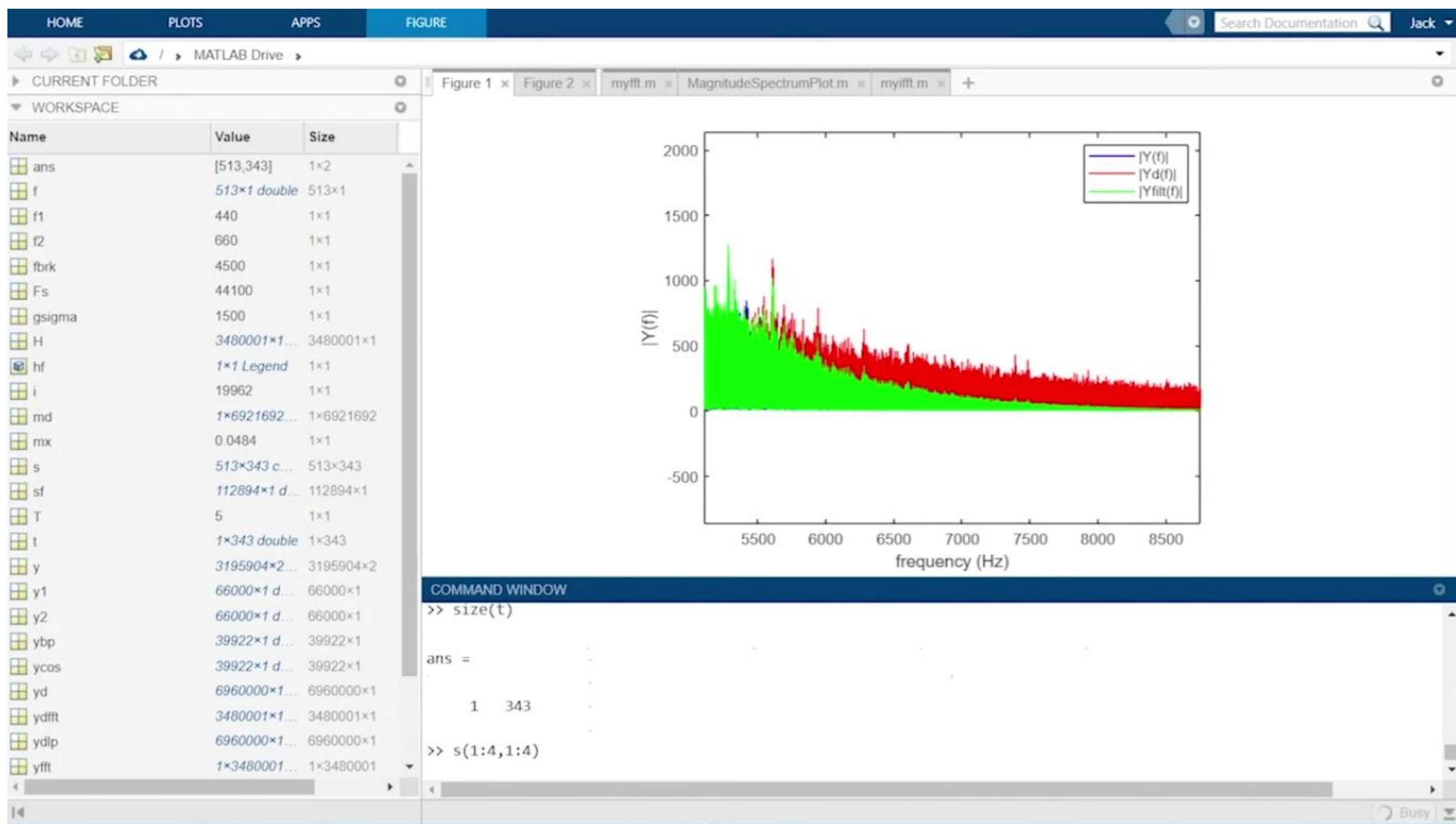


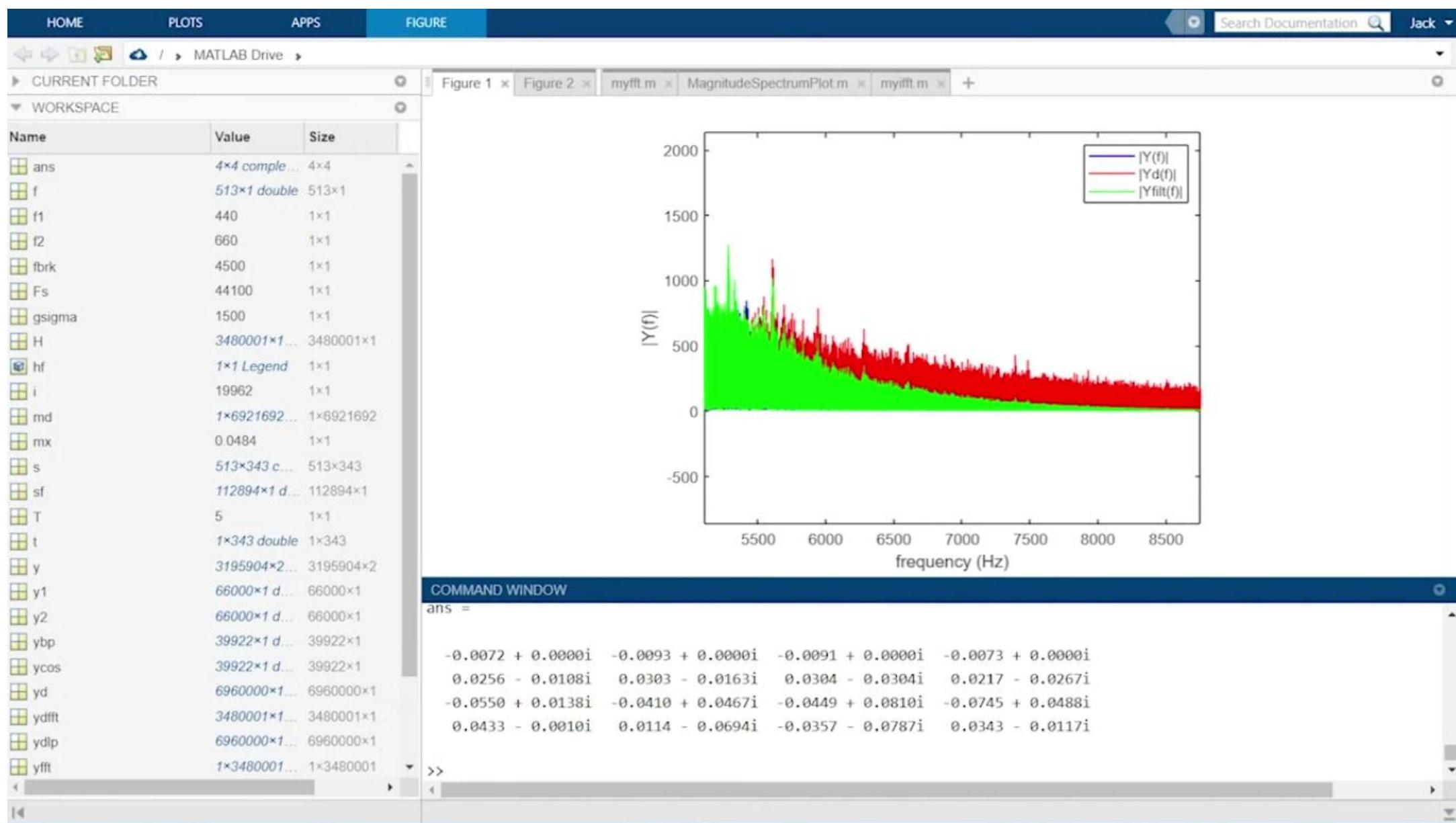


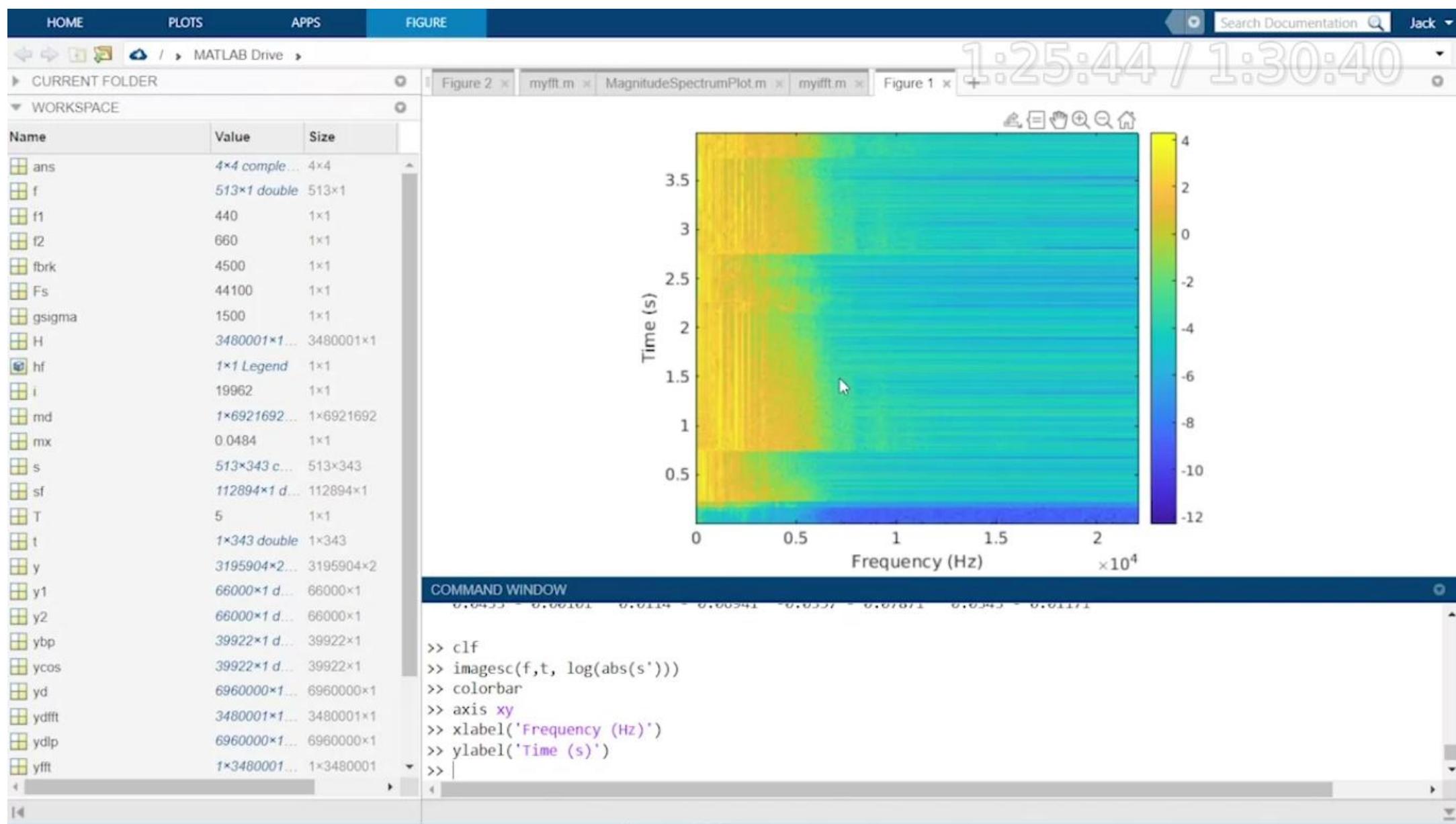


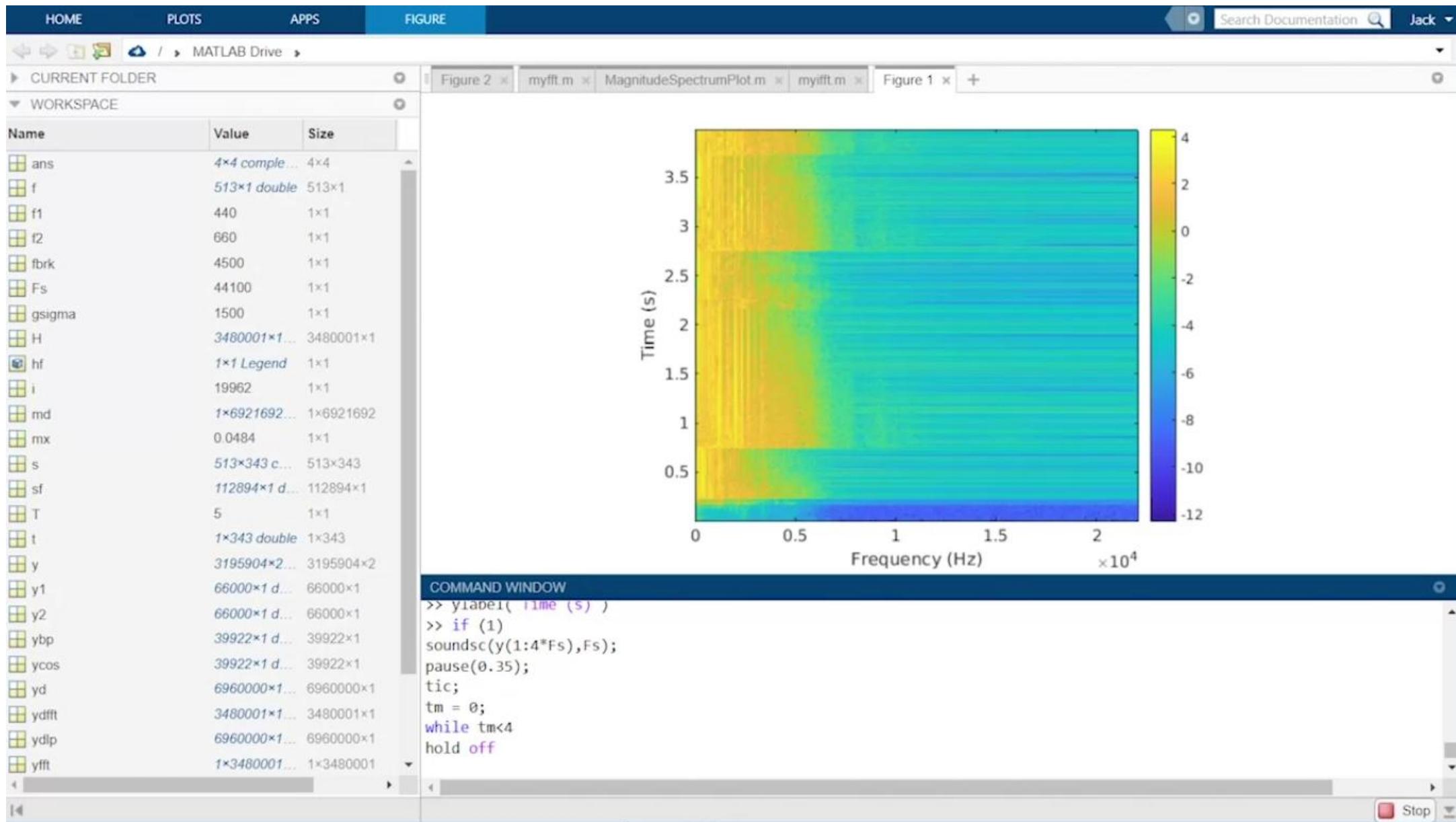


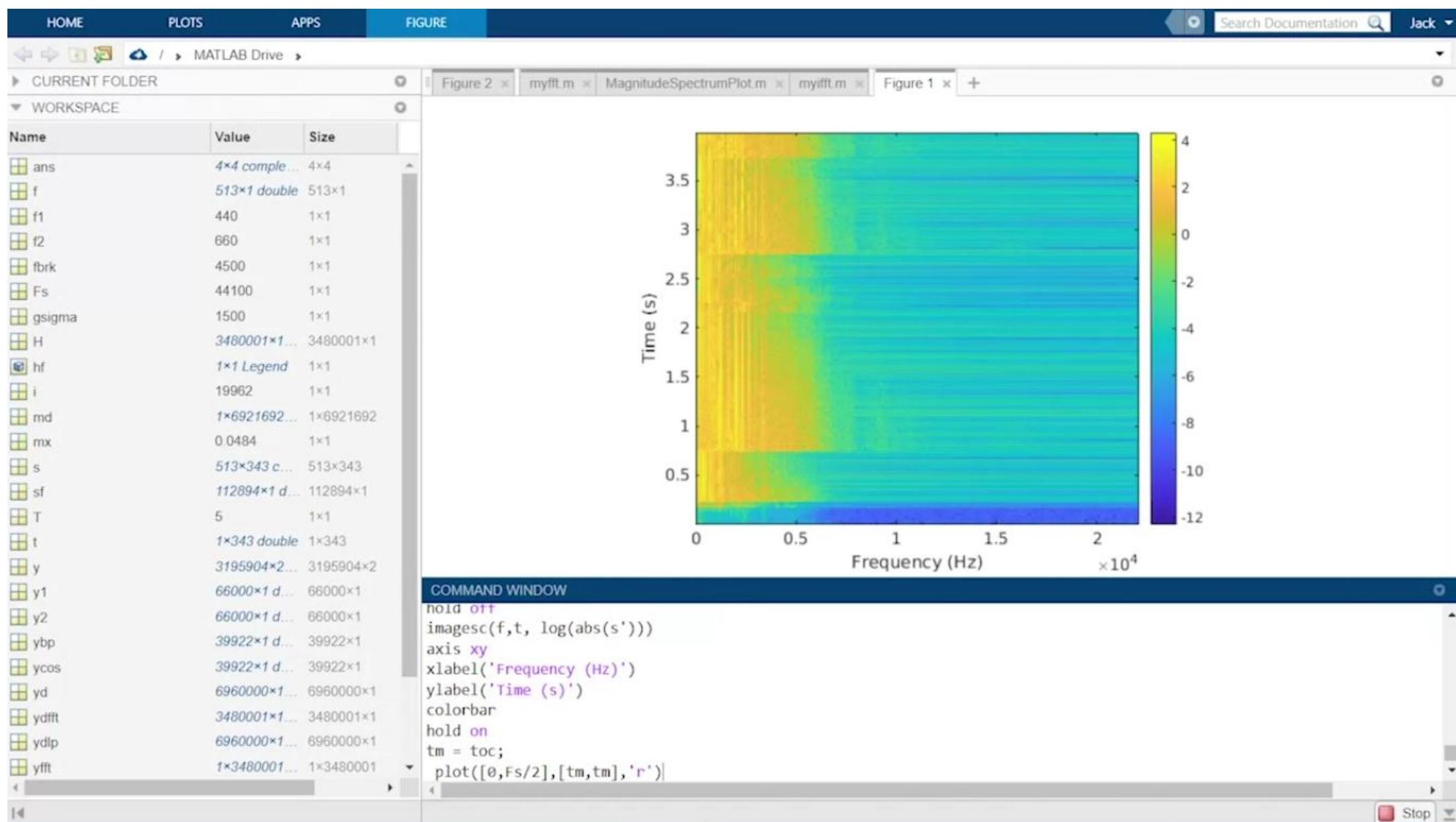


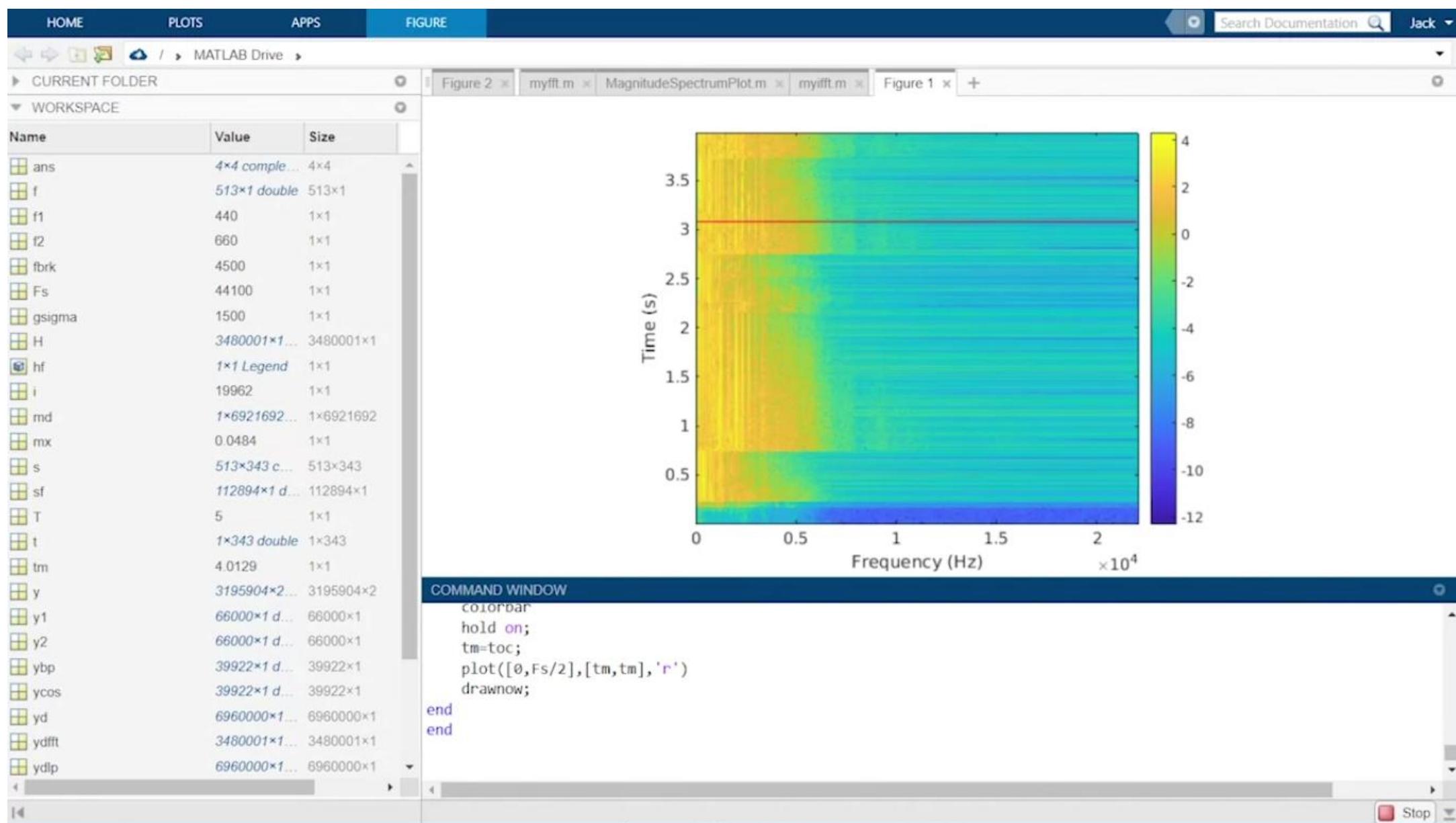














Introduction to Data, Signal, and Image Analysis with MATLAB®

Lesson 3.6 Sampling & Aliasing

Jack Noble



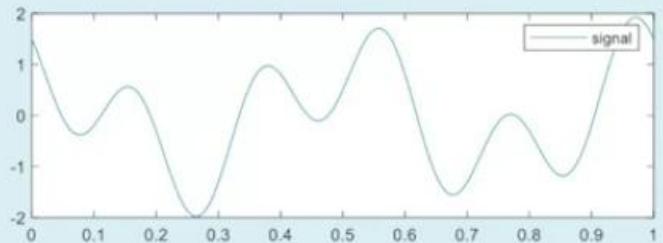
Introduction to Data, Signal, and Image Analysis with MATLAB®



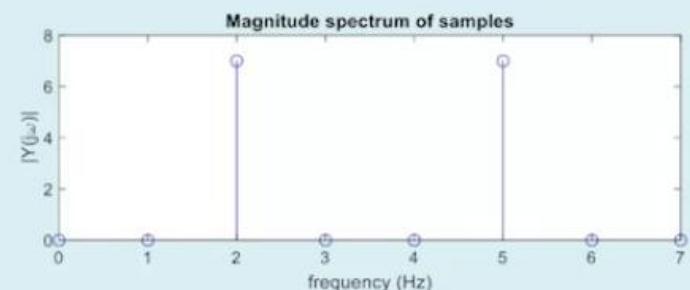
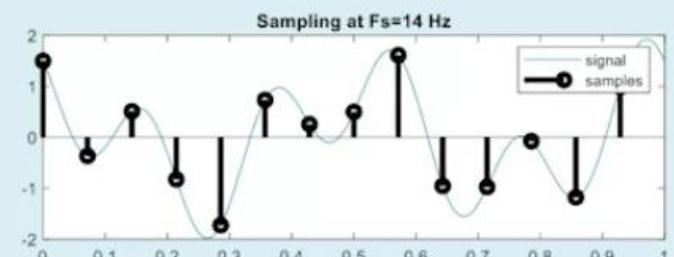
Sampling frequency $F_s \rightarrow$
 $Y_{fft}(f): f \in \left(0, \frac{F_s}{2}\right)$

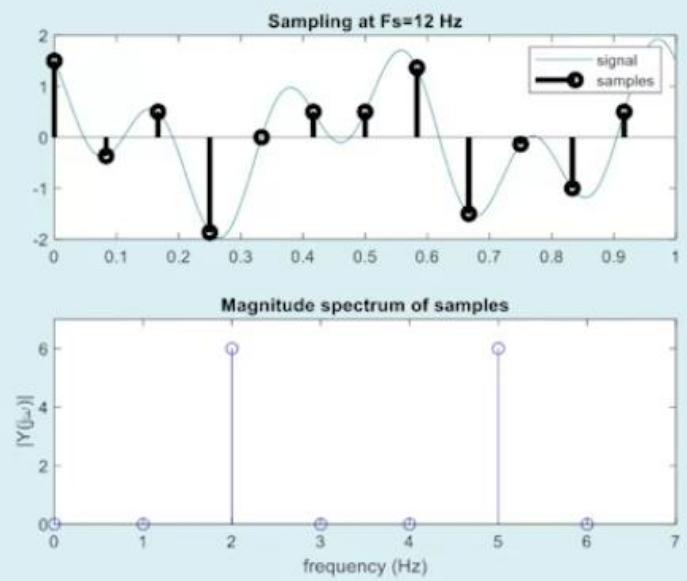
Nyquist rate: $2f_{\max}$

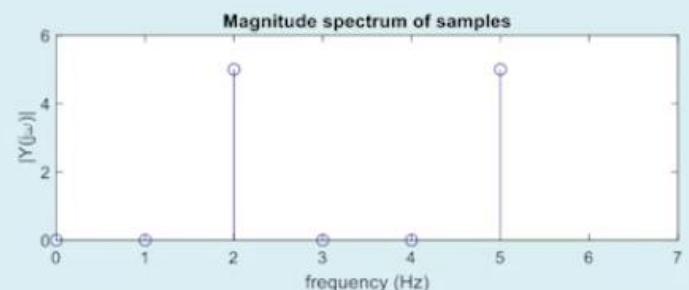
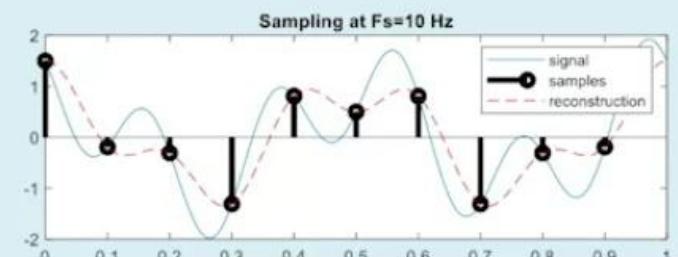
If $F_s > 2f_{\max}$, then no aliasing occurs



$$y(t) = \cos(4\pi t) + \cos(10\pi t)$$



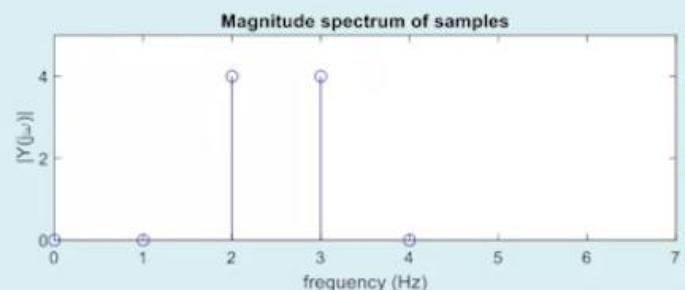
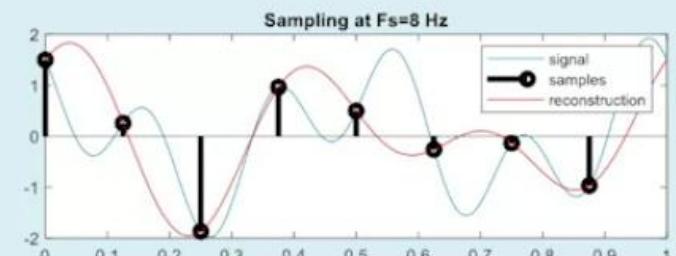
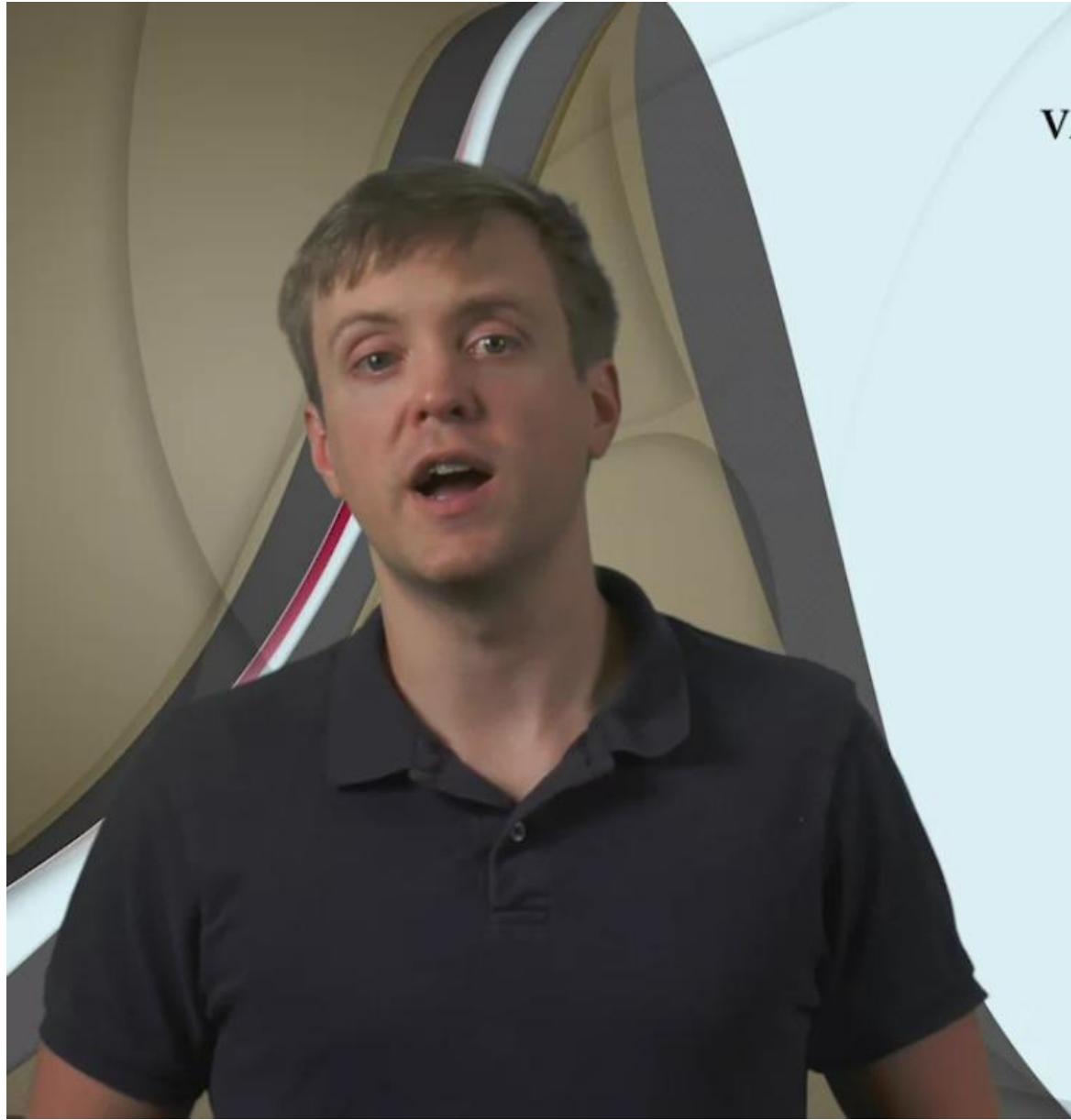


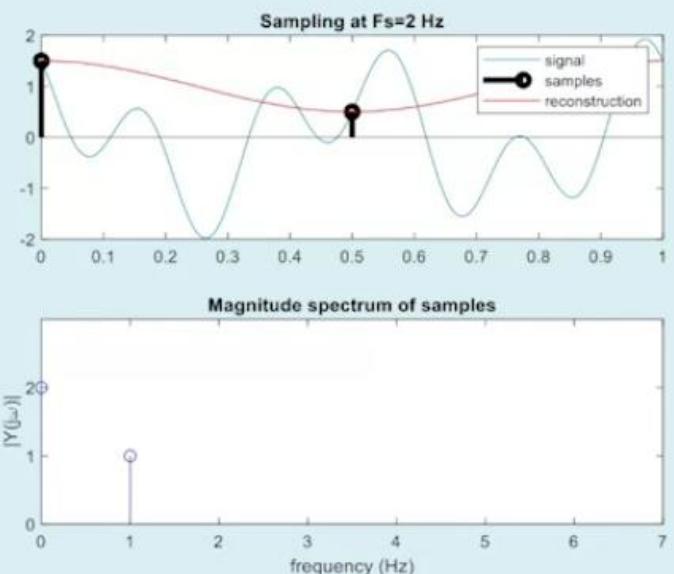


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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
Fs	12	1x1	double
nT	1x13 double	1x13	double
Ts	0.0833	1x1	double

```
>> f1 = 2;
>> f2 = 5;
>> Fs = 12;
>> Ts = 1/Fs;
>> nT = 0:Ts:1;
>> xn = cos(2*pi*f1*nT) + cos(2*pi*f2*nT)
```

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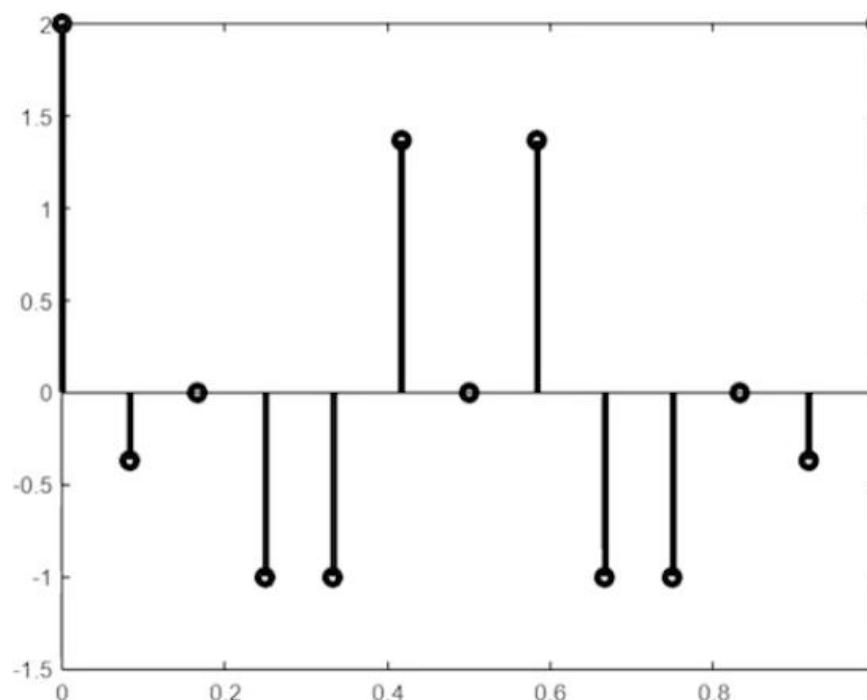
MATLAB Drive >

CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
f3	1x11 double	1x11	double
Fs	12	1x1	double
nT	1x13 double	1x13	double
t	1x1001 do...	1x1001	double
Ts	0.0833	1x1	double
xn	1x13 double	1x13	double

Figure 1 x +



COMMAND WINDOW

```
>> stem(nT, xn, 'k', 'LineWidth',3)
>> t = [0:0.001:1];
>> f3 = [5, 7, 17, 19, 29, 31, 41, 43, 53, 55, 65];
>> for i=1:length(f3)
    clf
    stem(nT, xn, 'k', 'LineWidth',3)
    axis([0,1,-2,2])|
```

Stop

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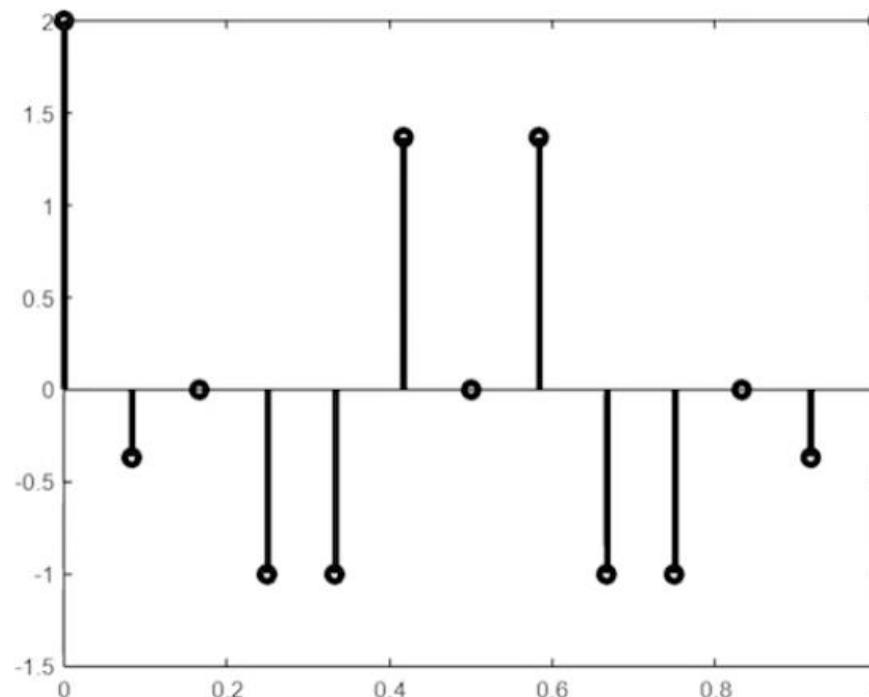
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WORKSPACE

Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
f3	1x11 double	1x11	double
Fs	12	1x1	double
nT	1x13 double	1x13	double
t	1x1001 double	1x1001	double
Ts	0.0833	1x1	double
xn	1x13 double	1x13	double

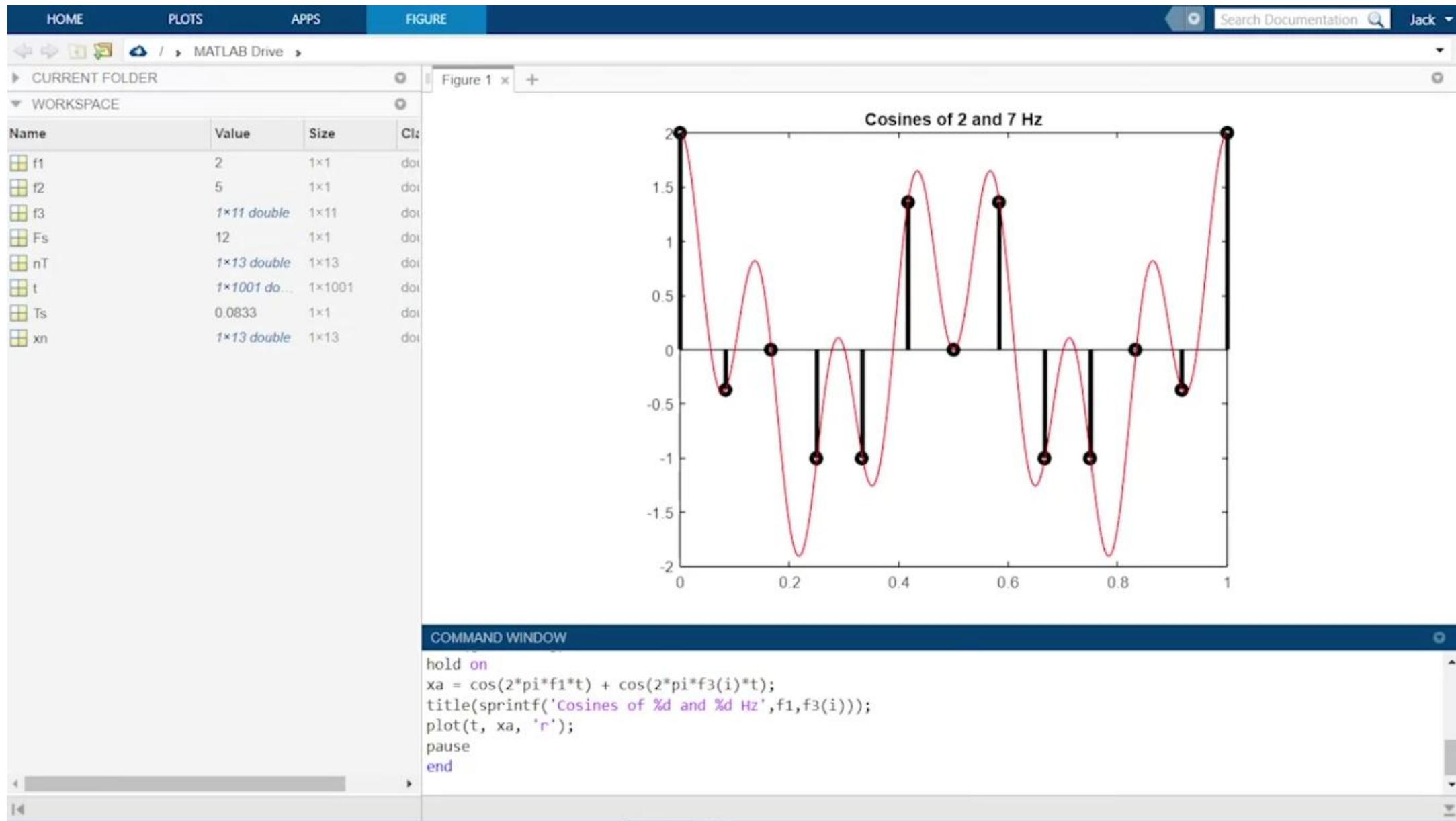
Figure 1 x +



COMMAND WINDOW

```
hold on
xa = cos(2*pi*f1*t) + cos(2*pi*f3(i)*t);
title(sprintf('Cosines of %d and %d Hz',f1,f3(i)));
plot(t, xa, 'r');
pause
end
```

Stop



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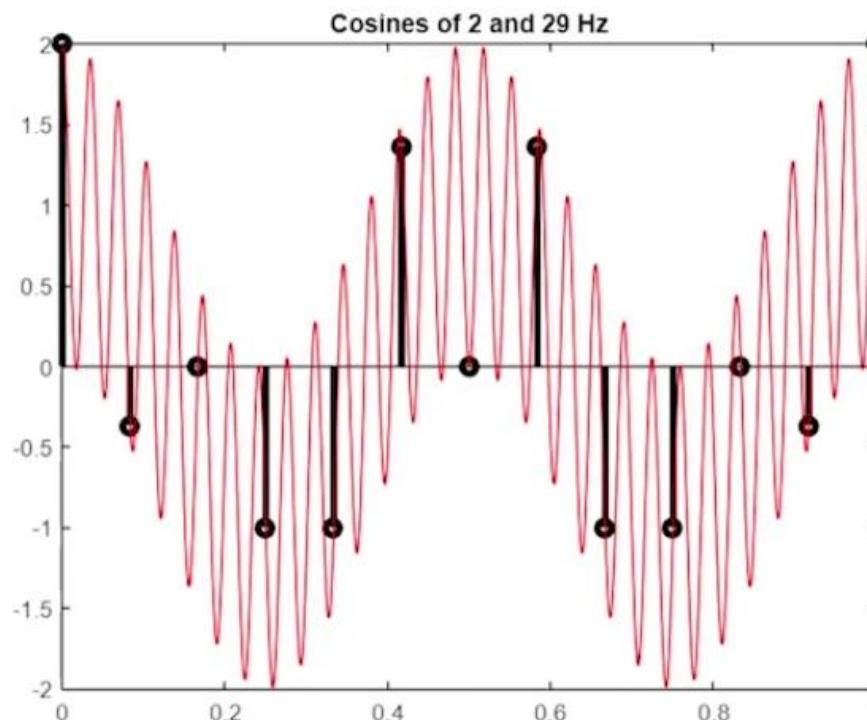
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WORKSPACE

Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
f3	1x11 double	1x11	double
Fs	12	1x1	double
nT	1x13 double	1x13	double
t	1x1001 double	1x1001	double
Ts	0.0833	1x1	double
xn	1x13 double	1x13	double

Figure 1 x +



COMMAND WINDOW

```
hold on
xa = cos(2*pi*f1*t) + cos(2*pi*f3(i)*t);
title(sprintf('Cosines of %d and %d Hz',f1,f3(i)));
plot(t, xa, 'r');
pause
end
```

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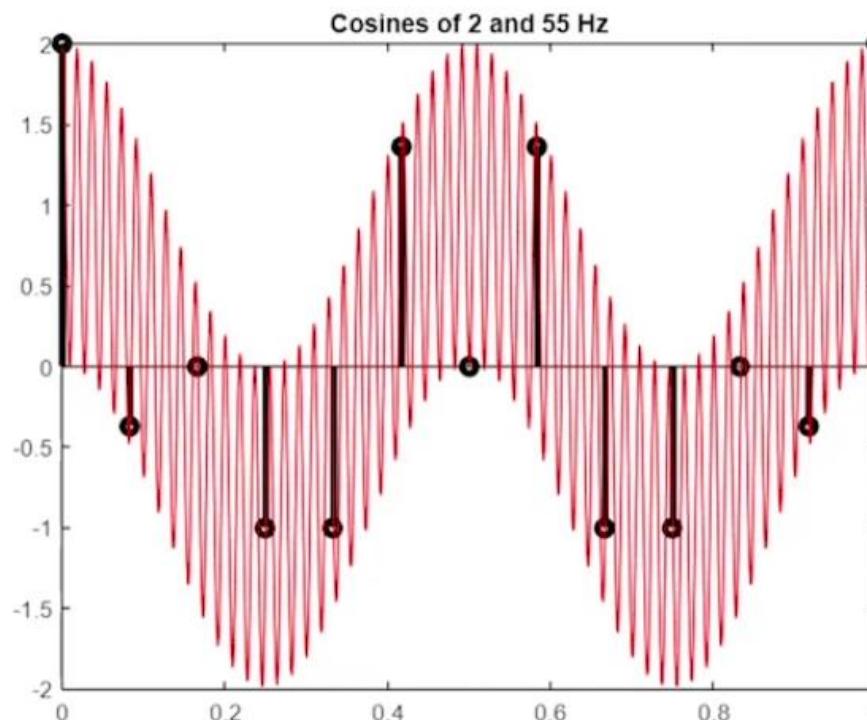
MATLAB Drive >

CURRENT FOLDER

WORKSPACE

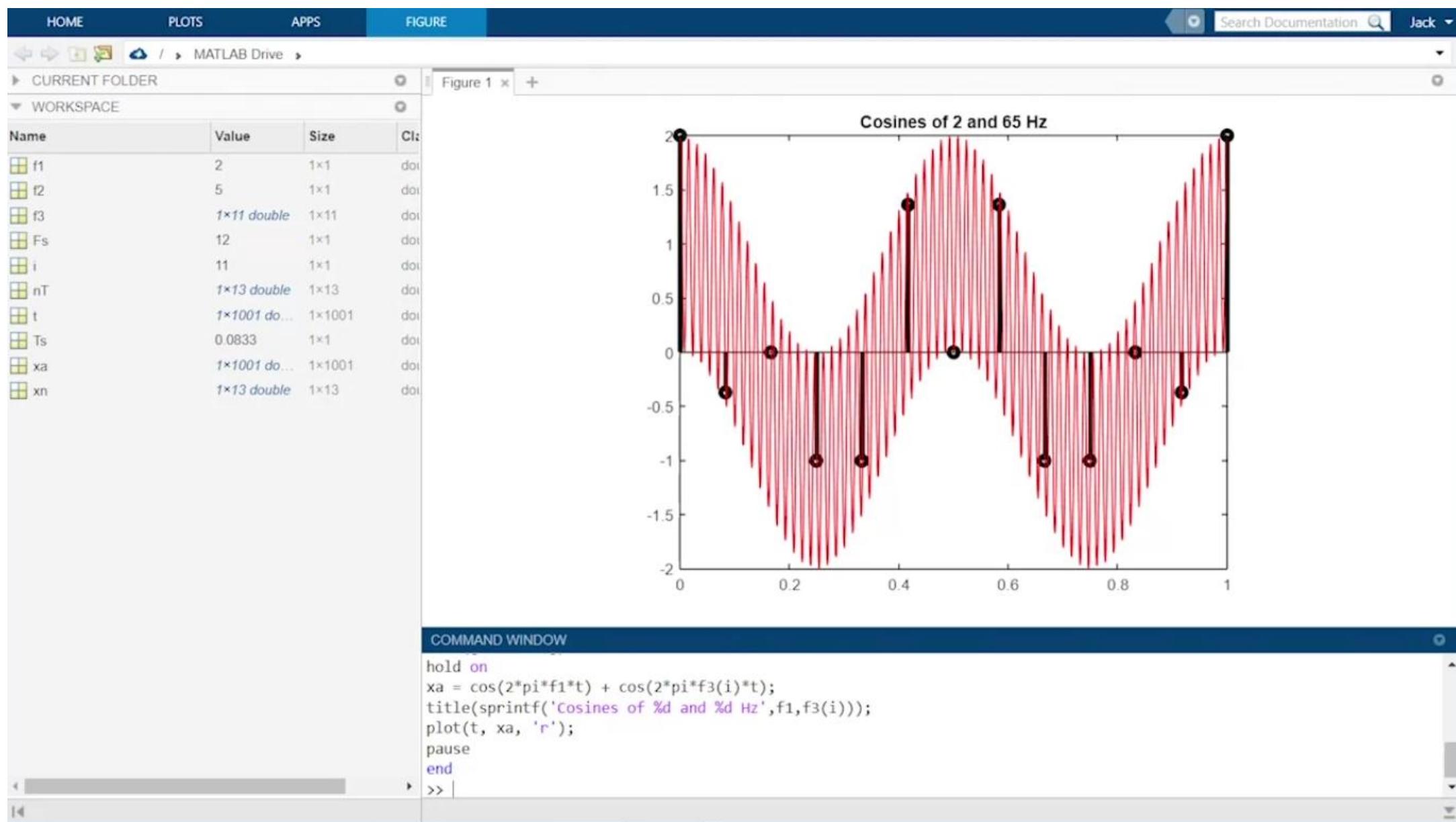
Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
f3	1x11 double	1x11	double
Fs	12	1x1	double
nT	1x13 double	1x13	double
t	1x1001 do...	1x1001	double
Ts	0.0833	1x1	double
xn	1x13 double	1x13	double

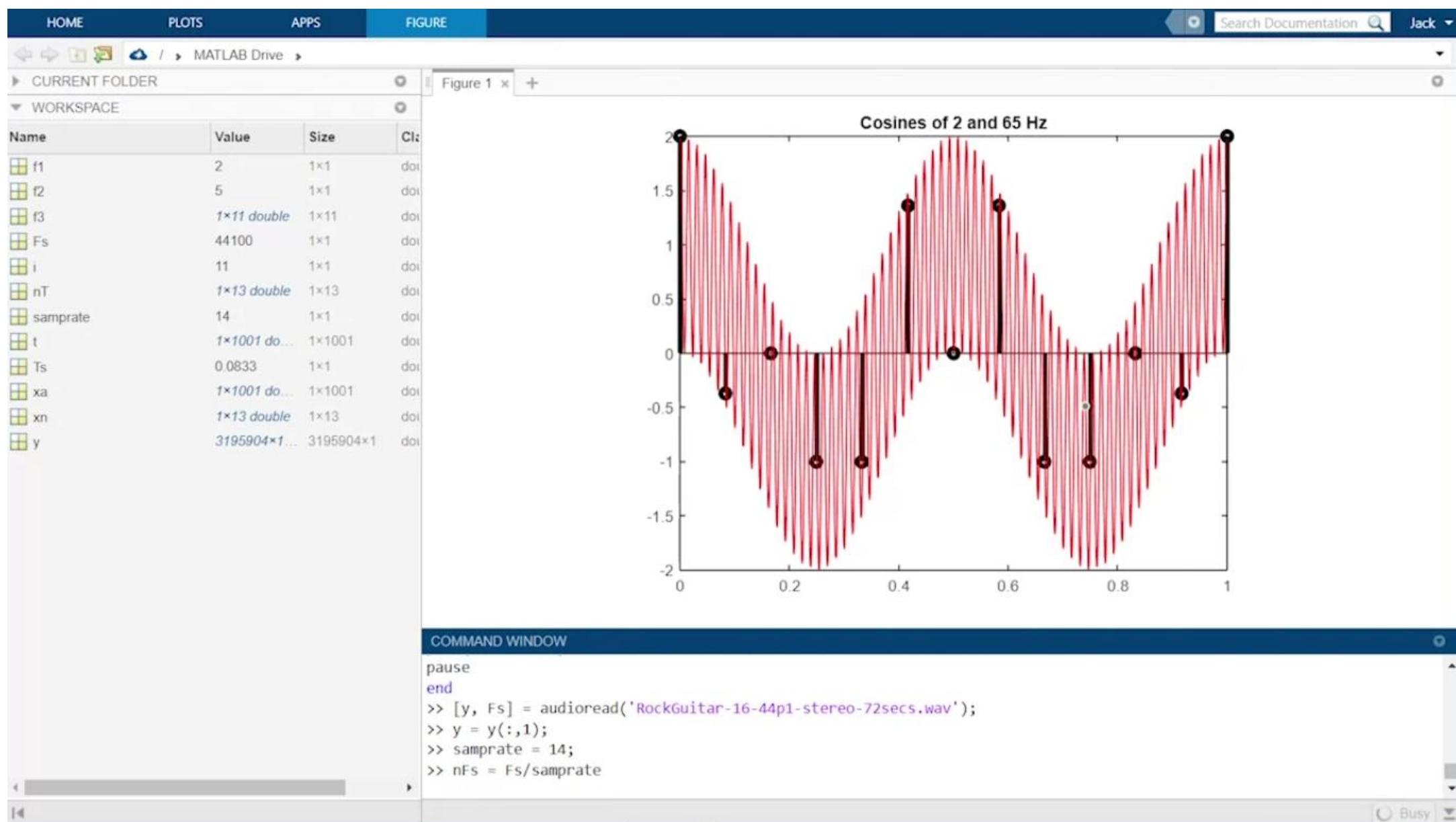
Figure 1 x +



COMMAND WINDOW

```
hold on
xa = cos(2*pi*f1*t) + cos(2*pi*f3(i)*t);
title(sprintf('Cosines of %d and %d Hz',f1,f3(i)));
plot(t, xa, 'r');
pause
end
```





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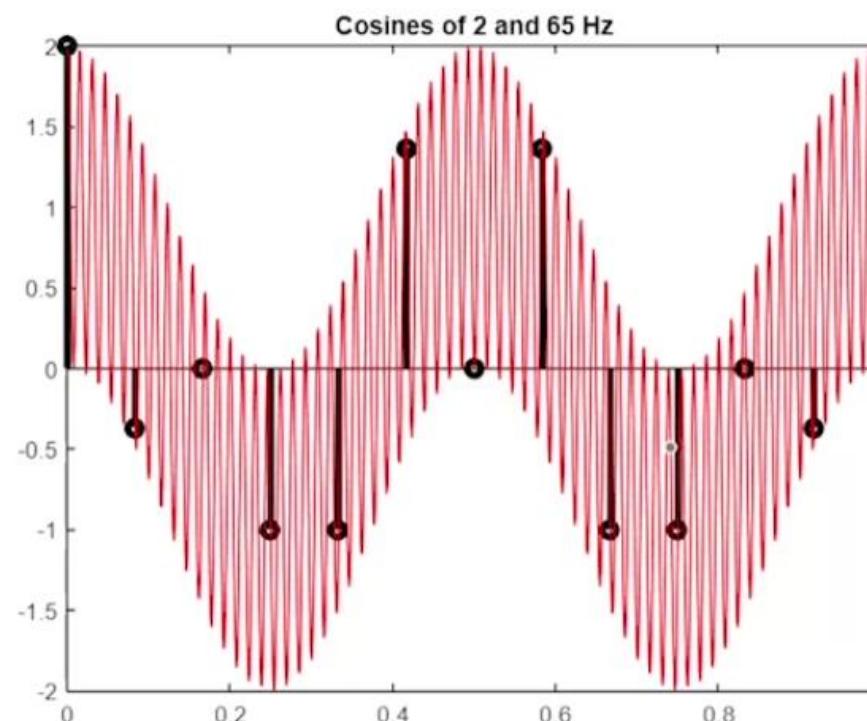
Jack

CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
f1	2	1x1	double
f2	5	1x1	double
f3	1x11 double	1x11	double
Fs	44100	1x1	double
i	11	1x1	double
nFs	3150	1x1	double
nT	1x13 double	1x13	double
sampreate	14	1x1	double
t	1x1001 double	1x1001	double
Ts	0.0833	1x1	double
xa	1x1001 double	1x1001	double
xn	1x13 double	1x13	double
y	3195904x1 double	3195904x1	double

Figure 1

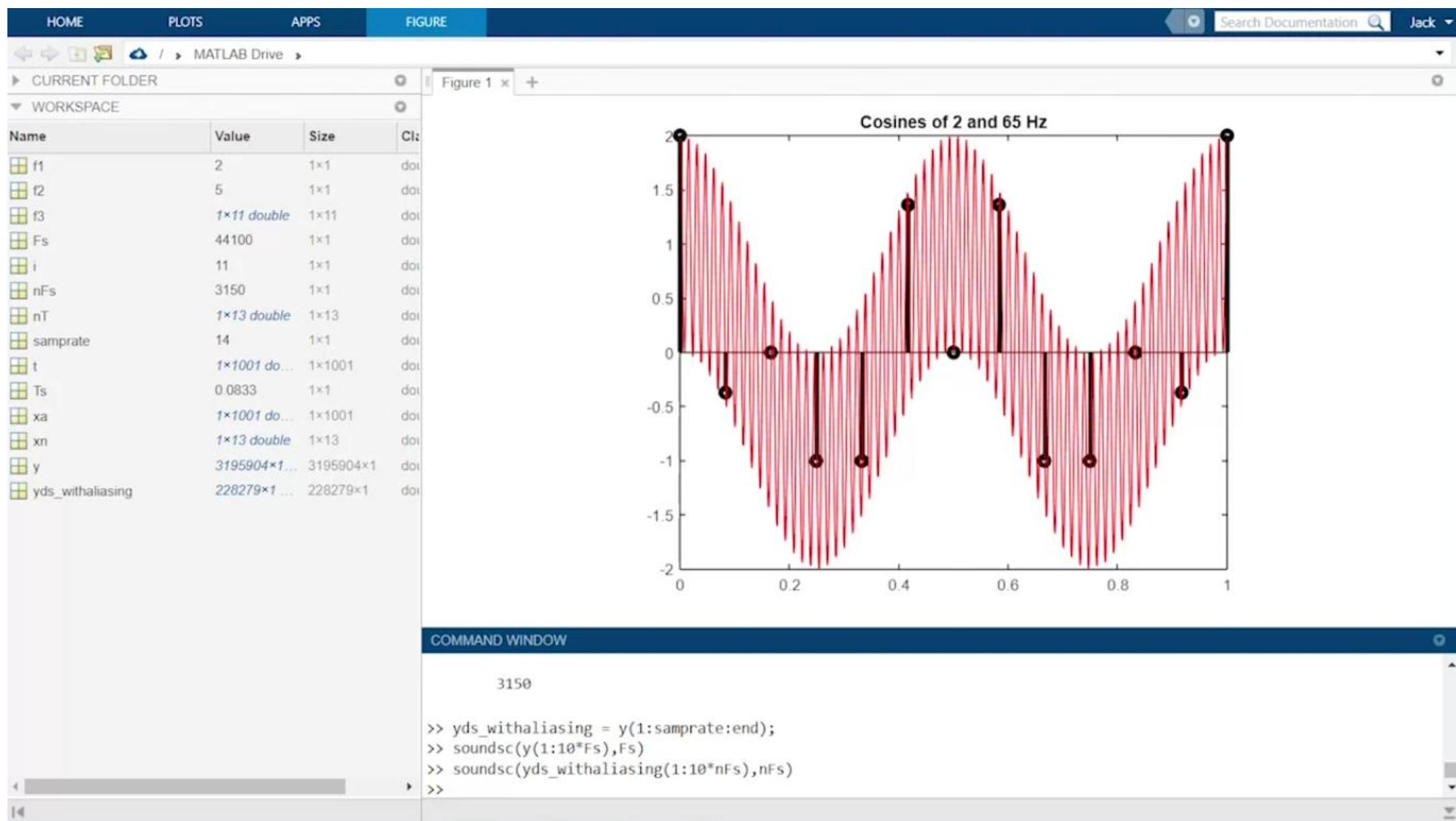


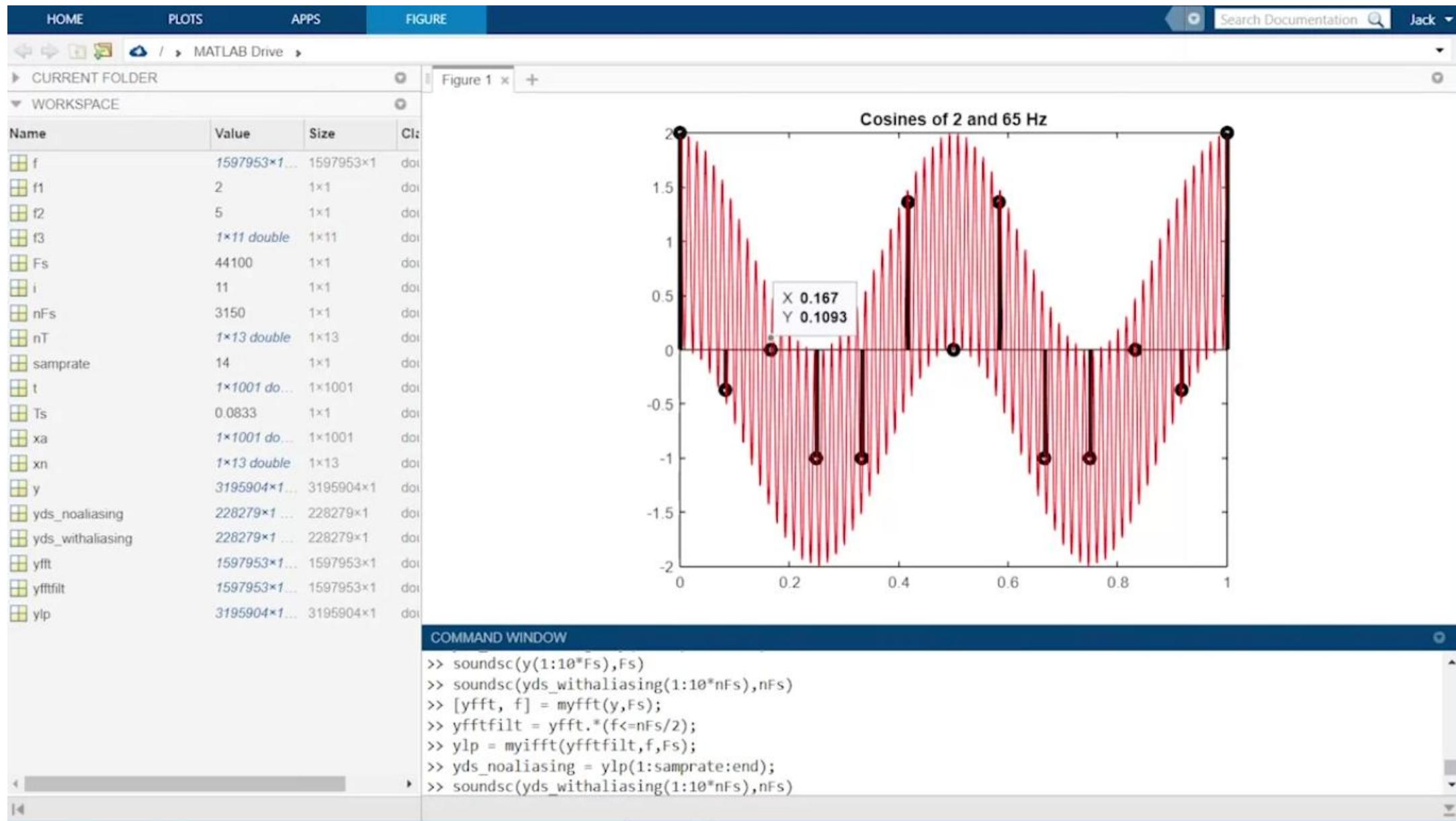
COMMAND WINDOW

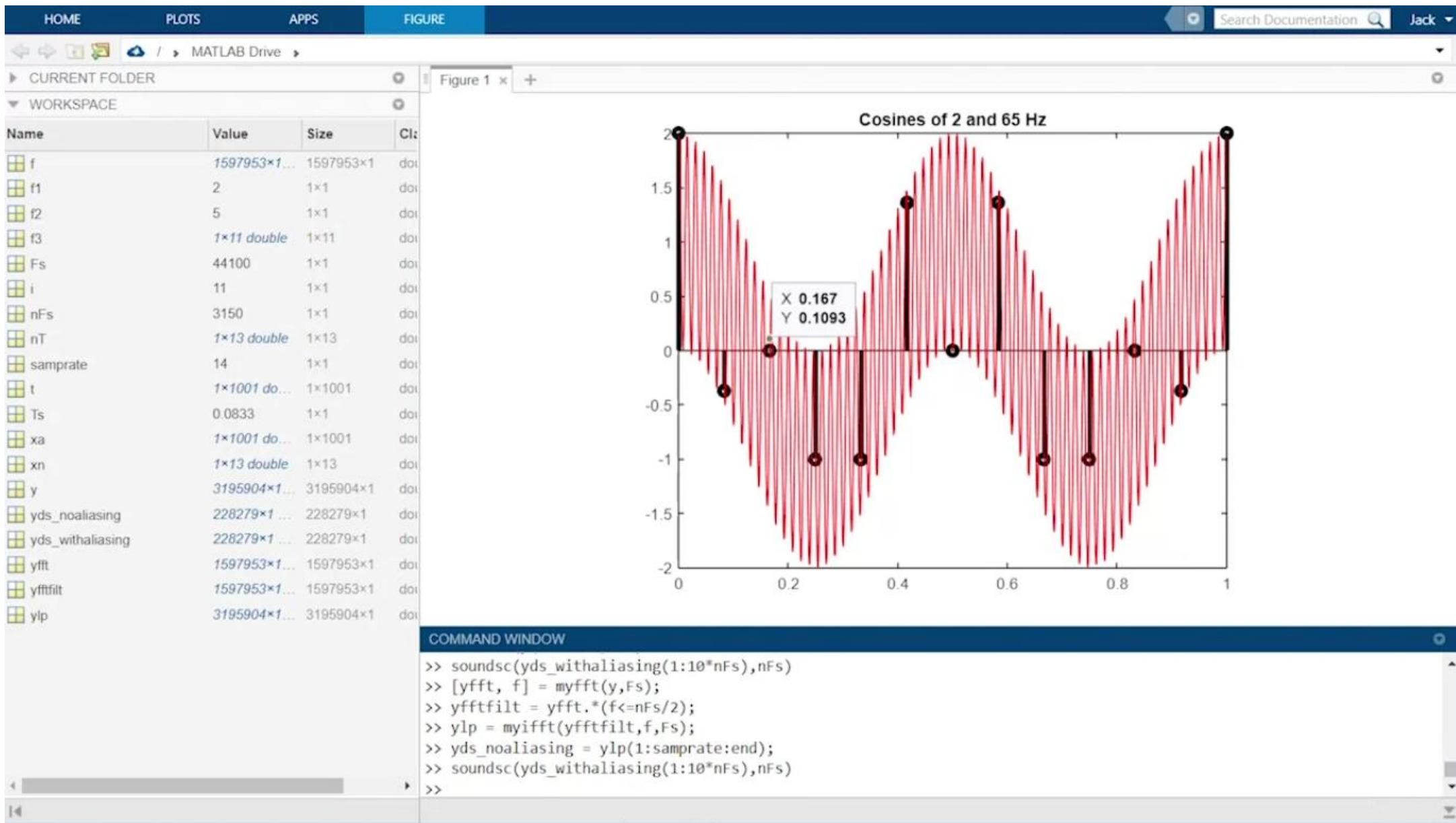
nFs =

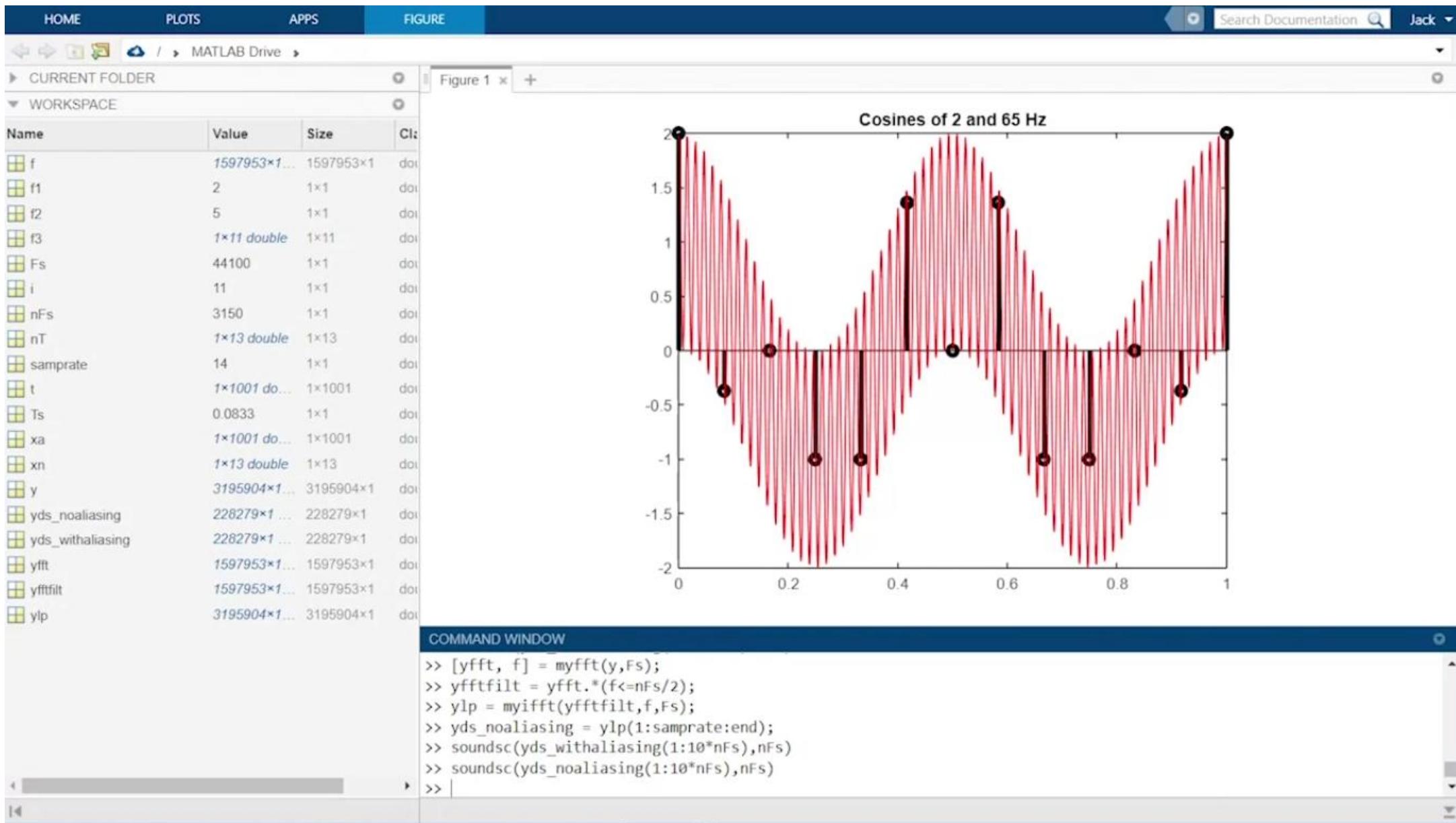
3150

>> yds withaliasing = |



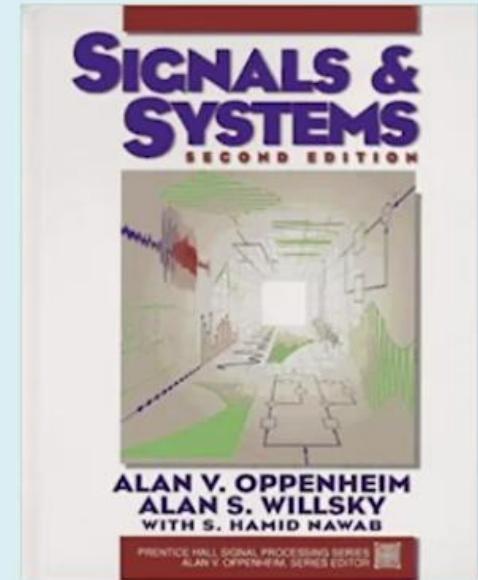








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