

# Lab Assignment – 07 – Spring 2020

## Signal & Systems

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### Summary:

- This assignment mainly dealt with determining the Nyquist rate of a signal and sampling a given signal with different sampling rates  $f_s$ .
- The main thing we learnt from this exercise is that we can represent a continuous signal in discrete form by sampling it

1) Given the following signal, we had to determine and plot the Fourier transform and then determine the Nyquist sampling rate.

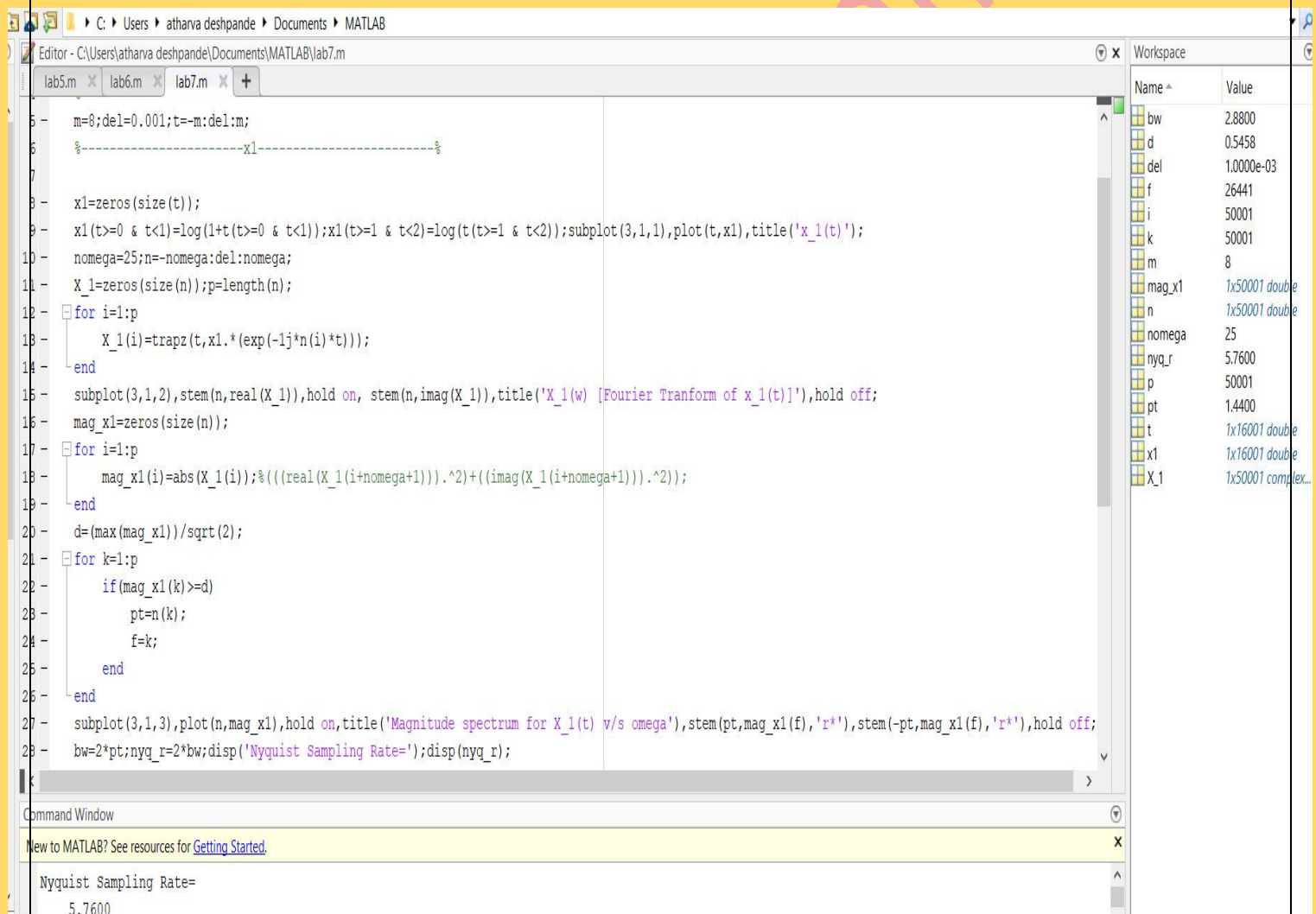
$$x(t) = \begin{cases} \ln(1+t) & 0 < t < 1 \\ \ln(t) & 1 \leq t < 2 \\ 0 & \text{elsewhere} \end{cases}$$

-> First, we'll create the code for finding the Fourier transform of the signal  $x(t)$ .

->We'll find out the x-point where the y-value is just  $(1/\sqrt{2}) \times (\text{peak value})$ . Then as the graph comes out to be symmetric, we'll double the x-point to get the bandwidth. Nyquist rate =  $2 \times \text{Bandwidth}$ .

->Finally, we'll display the Nyquist rate on the command window.

Here's the code:

A screenshot of the MATLAB environment. The Editor window shows a script 'lab7.m' with MATLAB code for signal processing. The Workspace window on the right lists variables and their values. The Command Window at the bottom displays the output 'Nyquist Sampling Rate= 5.7600'.

```
5 m=8;del=0.001;t=-m:del:m;
6 %-----x1-----%
7
8 x1=zeros(size(t));
9 x1(t>=0 & t<1)=log(1+t(t>=0 & t<1));x1(t>=1 & t<2)=log(t(t>=1 & t<2));subplot(3,1,1),plot(t,x1),title('x_1(t)');
10 nomega=25;n=-nomega:del:nomega;
11 X_1=zeros(size(n));p=length(n);
12 for i=1:p
13     X_1(i)=trapz(t,x1.*(exp(-1j*n(i)*t)));
14 end
15 subplot(3,1,2),stem(n,real(X_1)),hold on, stem(n,imag(X_1)),title('X_1(w) [Fourier Tranform of x_1(t)]'),hold off;
16 mag_x1=zeros(size(n));
17 for i=1:p
18     mag_x1(i)=abs(X_1(i));%(((real(X_1(i+nomega+1))).^2)+((imag(X_1(i+nomega+1))).^2));
19 end
20 d=(max(mag_x1))/sqrt(2);
21 for k=1:p
22     if(mag_x1(k)>=d)
23         pt=n(k);
24         f=k;
25     end
26 end
27 subplot(3,1,3),plot(n,mag_x1),hold on,title('Magnitude spectrum for X_1(t) v/s omega'),stem(pt,mag_x1(f),'r*'),stem(-pt,mag_x1(f),'r*'),hold off;
28 bw=2*pt;nyq_r=2*bw;disp('Nyquist Sampling Rate=');disp(nyq_r);
```

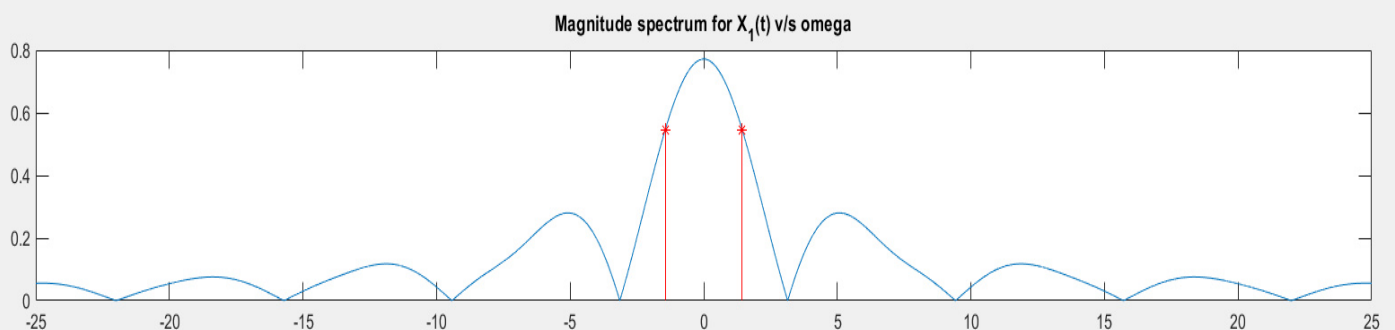
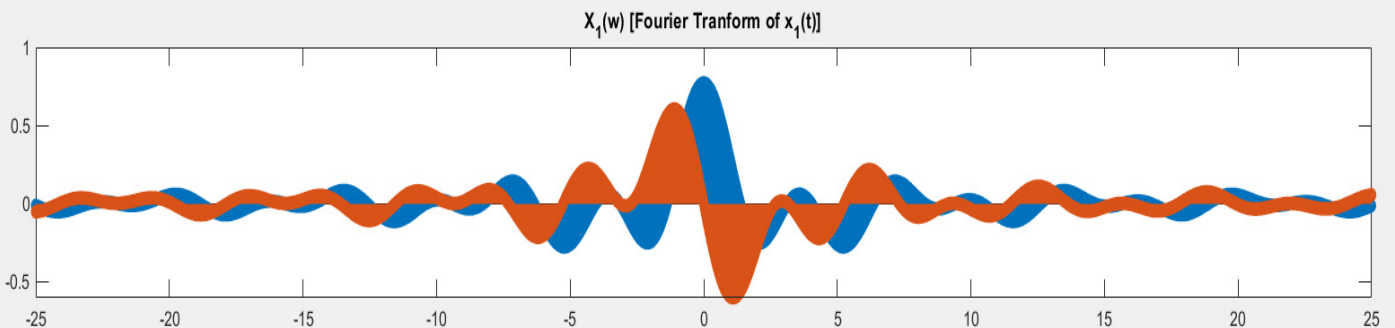
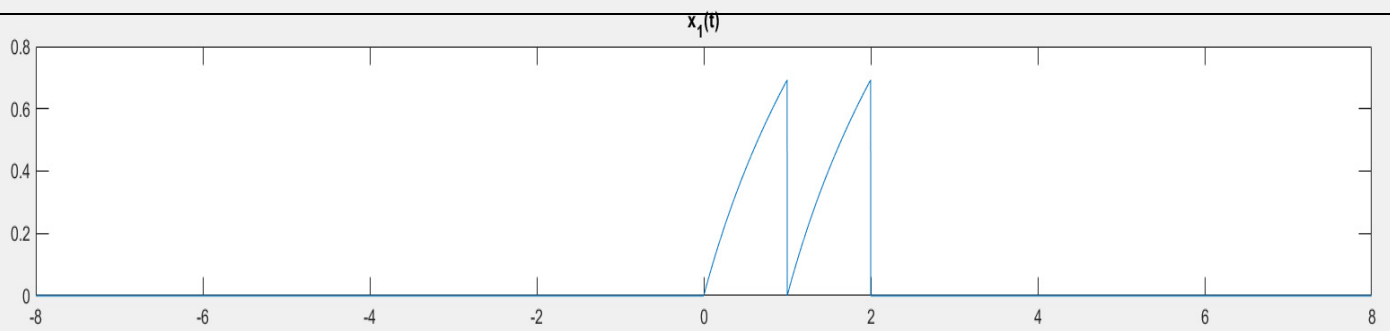
Name	Value
bw	2.8800
d	0.5458
del	1.0000e-03
f	26441
i	50001
k	50001
m	8
mag_x1	1x50001 double
n	1x50001 double
nomega	25
nyq_r	5.7600
p	50001
pt	1.4400
t	1x16001 double
x1	1x16001 double
X_1	1x50001 complex...

Command Window

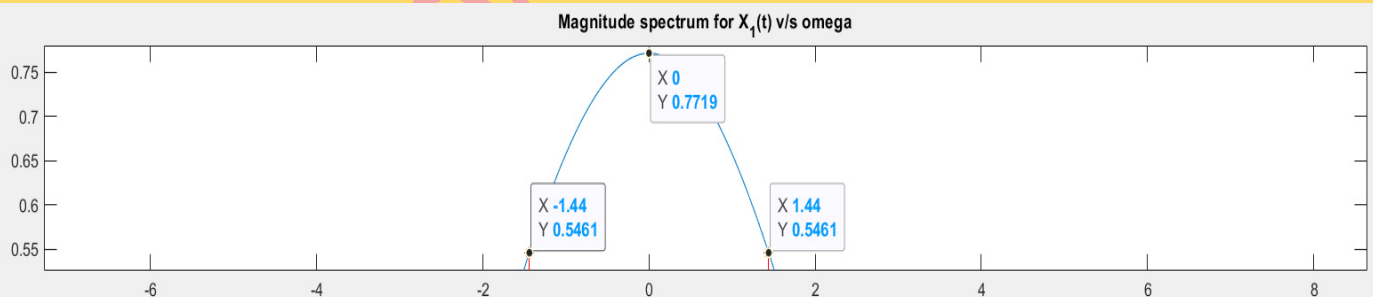
New to MATLAB? See resources for [Getting Started](#).

Nyquist Sampling Rate=  
5.7600

Here's the output:



On a closer look at the 3<sup>rd</sup> graph,



What we can conclude from the combined output obtained from command window, graph and workspace is that for the given signal,

Bandwidth = 2.8800

Nyquist Sampling Rate = 5.760

2) For the given signal with  $f_0 = 4$ ,

$$x(t) = \exp(-0.1t) \times \cos(2\pi f_0 t + \pi/7)(u(t) - u(t - 1))$$

simulate and plot the sampled discrete signals at the following sampling rates

a)  $f_s = 2f_0$ , b)  $f_s = 3f_0$  and c)  $f_s = 10f_0$

->First, we'll create a train of impulse with heads having value equal to one.

->Then, we'll multiply those impulse to the given signal and thus get it's sampled discrete signal.

Here's the code:

(i) Before that let me clear the picture. At the end, it is necessary to have a train of impulse  $p(t)$ . It was suggested to use this method.

Dr. Anish Chand Turlapaty is presenting

$$p(t) \rightarrow \text{zeros}(\text{size}(t))$$
$$t == nT \quad T = \frac{1}{f_s}$$
$$\text{rem}(t, T) == 0$$
$$p(\text{rem}(t, T) == 0) = 1$$

HAITANYA DATTU BIRUDUGADDA has left the meeting

RGB/Alpha (8-bit integer/channel) sRGB-ellie-V2-srgbtrcc

8096 x 4096 (80.8 MiB)

23%

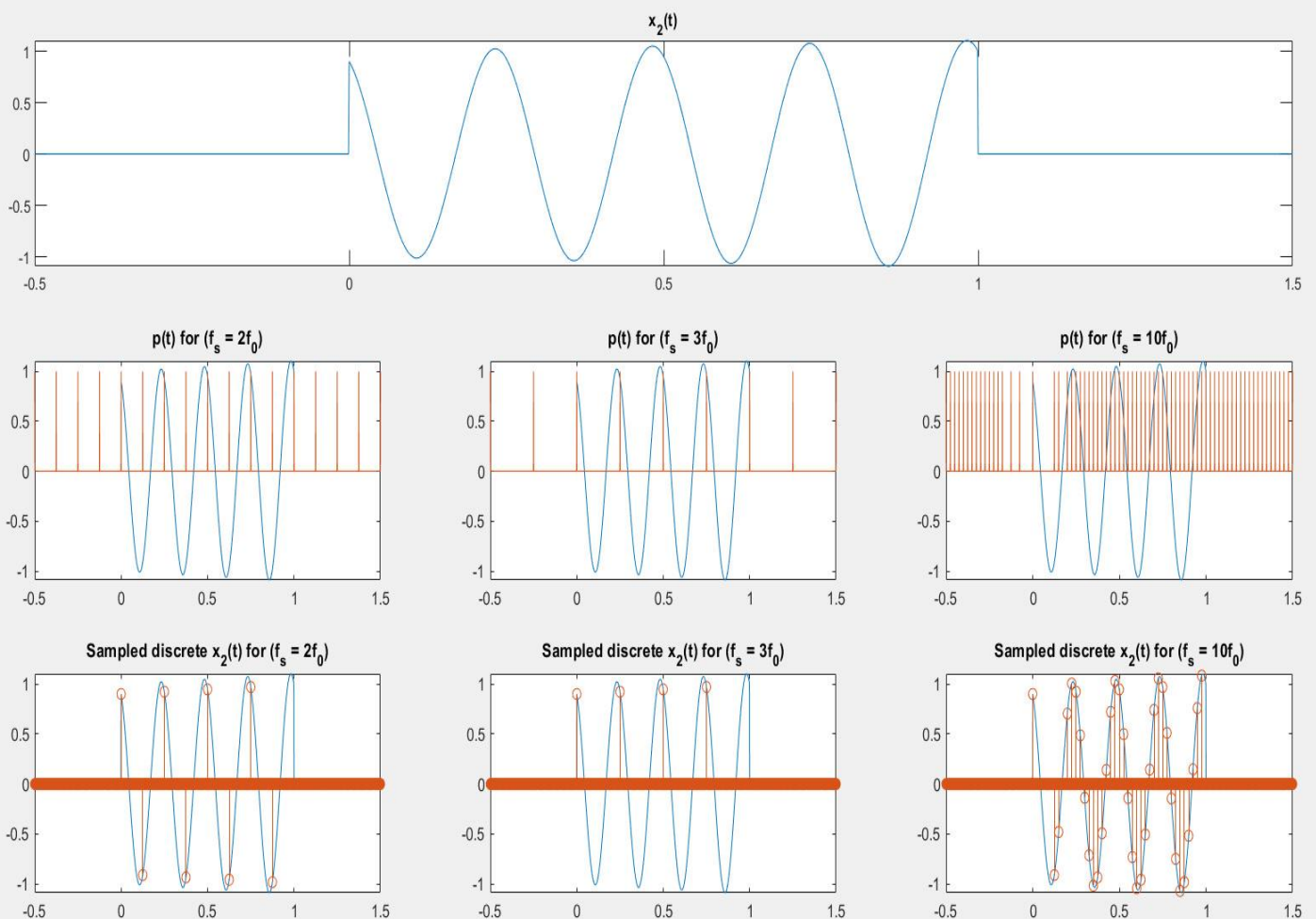
So, we implemented that method.

```

30 %-----x2-----%
31
32 t=-0.5:del:1.5;
33 f0=4;x2=zeros(size(t));
34 x2(t>=0 & t<1)=exp(0.1*t(t>=0 & t<1)).*cos((2*pi*f0*t(t>=0 & t<1))+(pi/7));subplot(3,3,[1,2,3]),plot(t,x2),title('x_2(t)');
35 %a)fs = 2f0
36 fs=2*f0;cap_t=1/fs;p=zeros(size(t));p(rem(t, cap_t)==0)=1;subplot(3,3,4),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 2f_0)'),hold off;
37 z=x2.*p;
38 subplot(3,3,7),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 2f_0)'),hold off;
39 %b)fs = 3f0
40 fs=3*f0;cap_t=1/fs;p=zeros(size(t));p(rem(t, cap_t)==0)=1;subplot(3,3,5),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 3f_0)'),hold off;
41 z=x2.*p;
42 subplot(3,3,8),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 3f_0)'),hold off;
43 %c)fs = 10f0
44 fs=10*f0;cap_t=1/fs;p=zeros(size(t));p(rem(t, cap_t)==0)=1;subplot(3,3,6),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 10f_0)'),hold off;
45 z=x2.*p;
46 subplot(3,3,9),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 10f_0)'),hold off;

```

We got this:





## Observation:

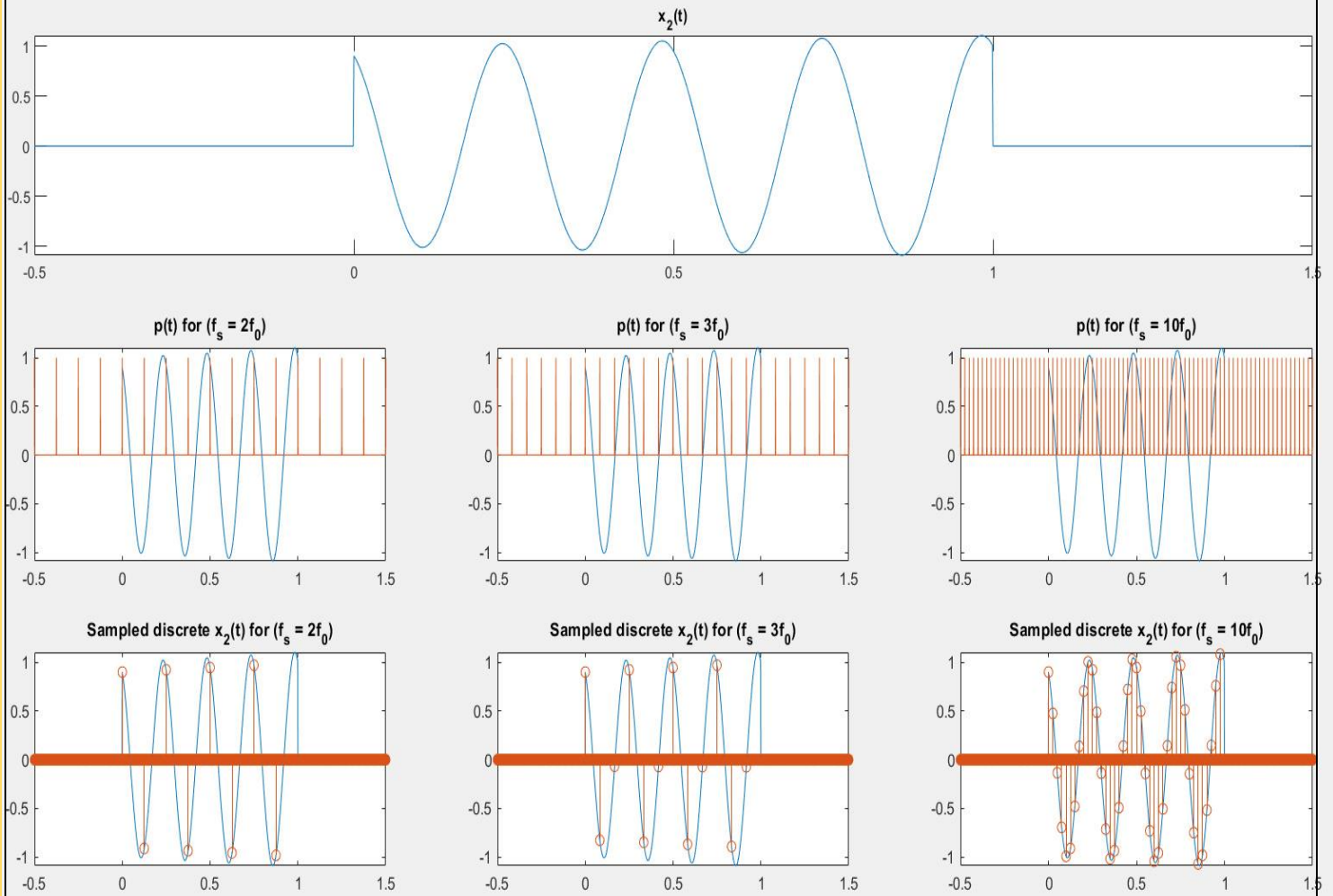
As you can see, when we increased  $f_s$  from  $2f_0$  to  $3f_0$  we got fewer samples, which ideally should not have happened as we are decreasing  $T$  (Since,  $T=1/f_s$ ). When we checked the values, they were actually what they were not supposed to be. It should be  $t=nxT$ . But those values were not showing up that frequently at the appropriate values. Also, there's a gap in between when  $f_s=10xf_0$ . So, we cross checked the output for  $f_s>10xf_0$ . Again, it had gaps at the same place every time. Hence, we need to find another method to generate a harmonic impulse train.

(ii) So, we made few changes and it solved the problem.

Here's the code:

```
30 %-----x2-----%
31
32 t=-0.5:del:1.5;
33 f0=4;x2=zeros(size(t));
34 x2(t>=0 & t<1)=exp(0.1*t(t>=0 & t<1)).*cos((2*pi*f0*t(t>=0 & t<1))+(pi/7));subplot(3,3,[1,2,3]),plot(t,x2),title('x_2(t)');
35 %a) fs = 2f0
36 fs=2*f0;cap_t=1/fs;p=zeros(size(t));p(1:(cap_t/del):end)=1;subplot(3,3,4),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 2f_0)'),hold off;
37 z=x2.*p;
38 subplot(3,3,7),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 2f_0)'),hold off;
39 %b) fs = 3f0
40 fs=3*f0;cap_t=1/fs;p=zeros(size(t));p(1:(cap_t/del):end)=1;subplot(3,3,5),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 3f_0)'),hold off;
41 z=x2.*p;
42 subplot(3,3,8),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 3f_0)'),hold off;
43 %c) fs = 10f0
44 fs=10*f0;cap_t=1/fs;p=zeros(size(t));p(1:(cap_t/del):end)=1;subplot(3,3,6),plot(t,x2),hold on,plot(t,p),title('p(t) for (f_s = 10f_0)'),hold off;
45 z=x2.*p;
46 subplot(3,3,9),plot(t,x2),hold on,stem(t,z),title('Sampled discrete x_2(t) for (f_s = 10f_0)'),hold off;
```

Here's the output:



Observation:

- Now we can conclude that the obtained graph is correct as when we increase the sampling rate the number of samples too increase.
- Also, we find no gap in the impulse train of any of the graphs.