EE386 Digital Signal Processing Lab **Jul-Dec 2021**

Experiment 2 Report

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The calculated value of α for the roll number : 191EE126 is

$$\alpha = 1 + mod(126, 4) = 3$$

Problem 1

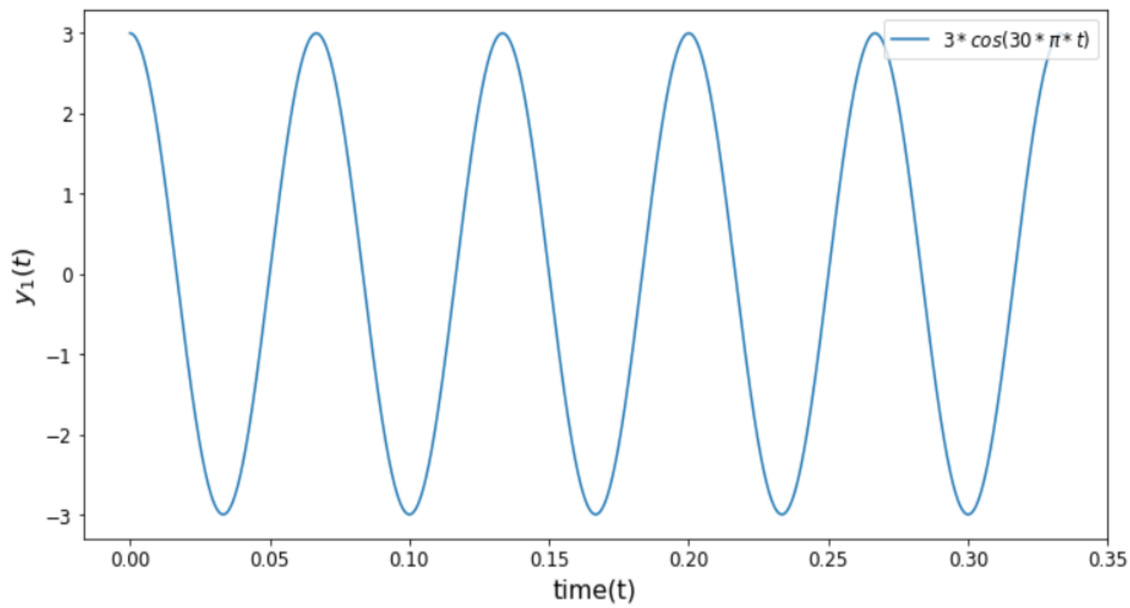
(Generating Cosine Signals)

(Solution)

The 3 given cosine signals of different frequencies and amplitudes are plotted against time :

1.

$$y_1(t) = 3cos(30\pi t)$$

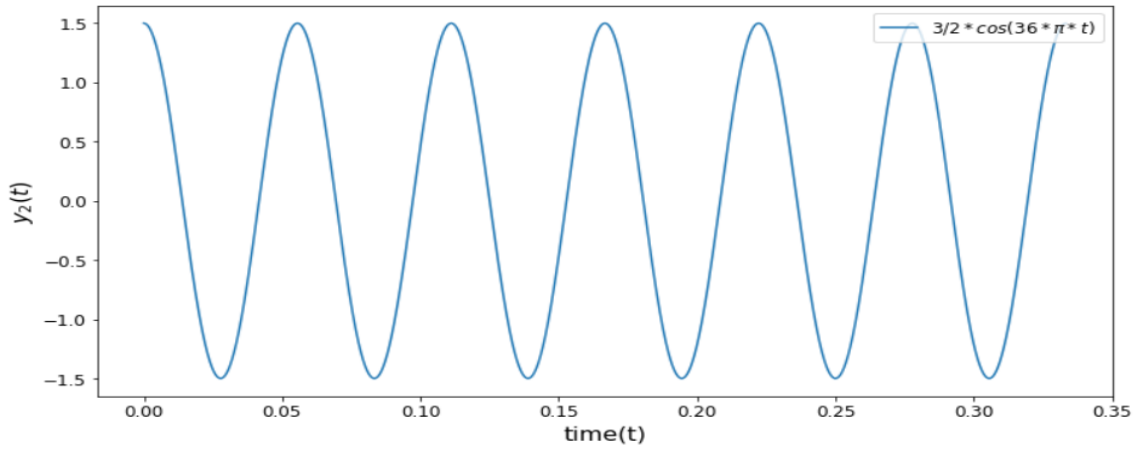


Frequency $= 5\alpha = 15$

Amplitude $= \alpha = 3$

2.

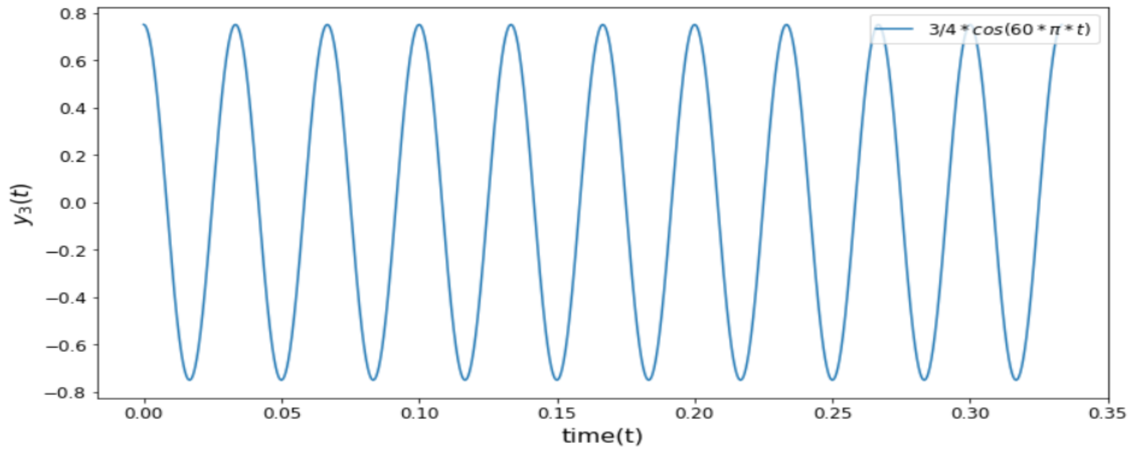
$$y_2(t) = \frac{3}{2}cos(36\pi t)$$



$$\text{Frequency} = 6\alpha = 18$$
$$\text{Amplitude} = \tfrac{\alpha}{2} = \tfrac{3}{2}$$

3.

$$y_3(t) = \frac{3}{4}cos(60\pi t)$$

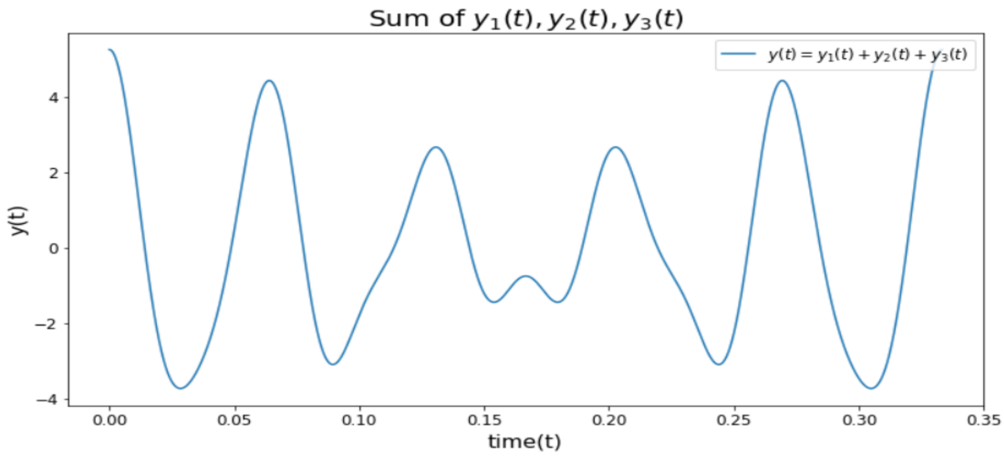


$$\text{Frequency} = 10\alpha = 30$$
$$\text{Amplitude} = \alpha = \tfrac{\alpha}{4} = \tfrac{3}{4}$$

(Generating Cumulative Signal)

(Solution)

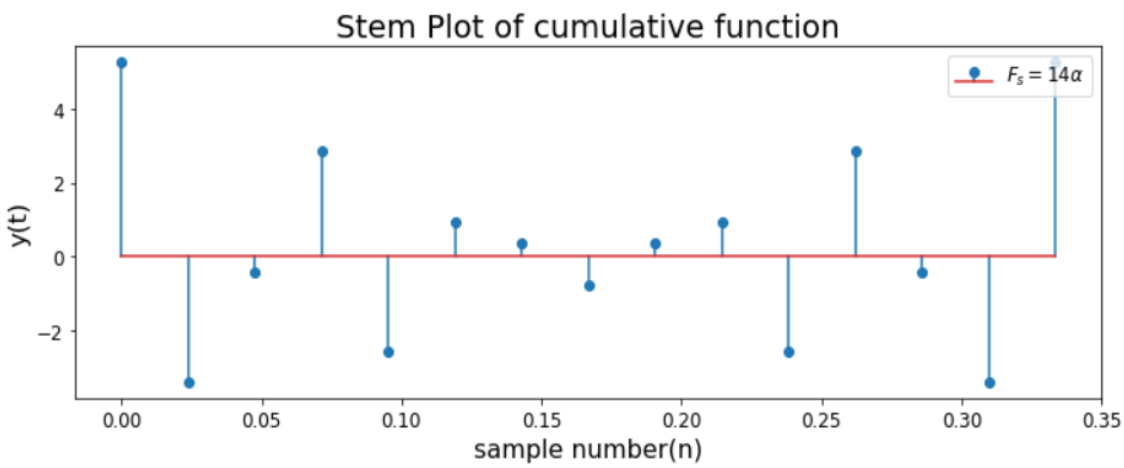
Sum of the three given signals is stored. When the cumulative signal is plotted against time, it consists of multiple frequencies.



(Different Sampling Frequency for Cumulative Signal)

(Solution)

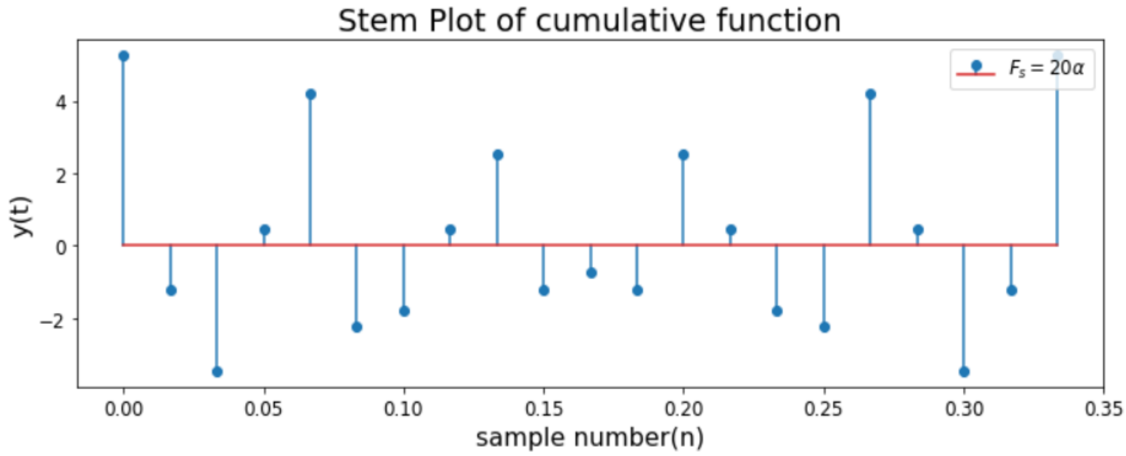
1. $F_s = 14\alpha = 42$



At $F_s = 14\alpha$, folding frequency is given by $\frac{F_s}{2} = 7\alpha$. At this folding frequency only the frequency 10α will get folded to 4α.

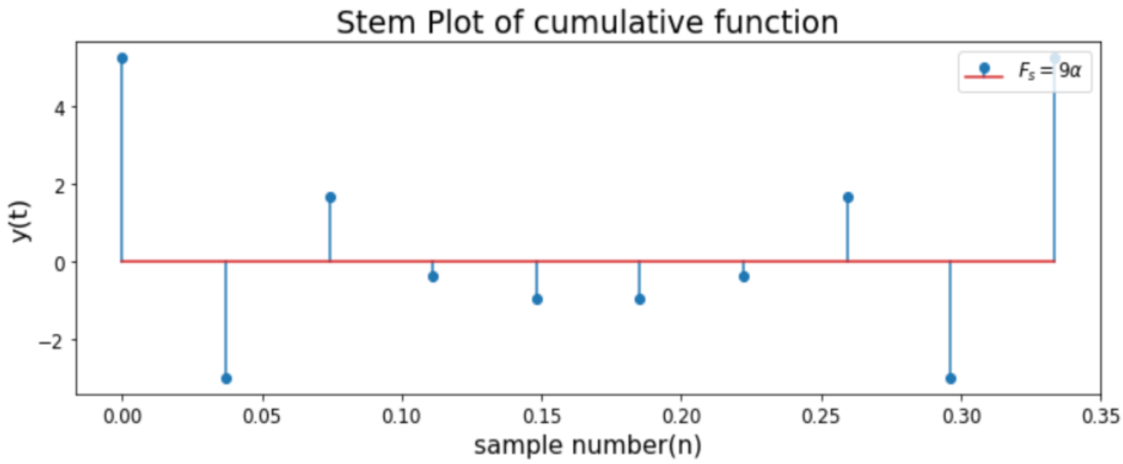
2. At Nyquist Rate of the Signal

The component of the signal which has the highest frequency is considered for Nyquist Rate. $F_s = 20\alpha = 60$



At $F_s = 20\alpha$, none of the frequencies components are folded or aliased since all are less than folding frequency 10α.

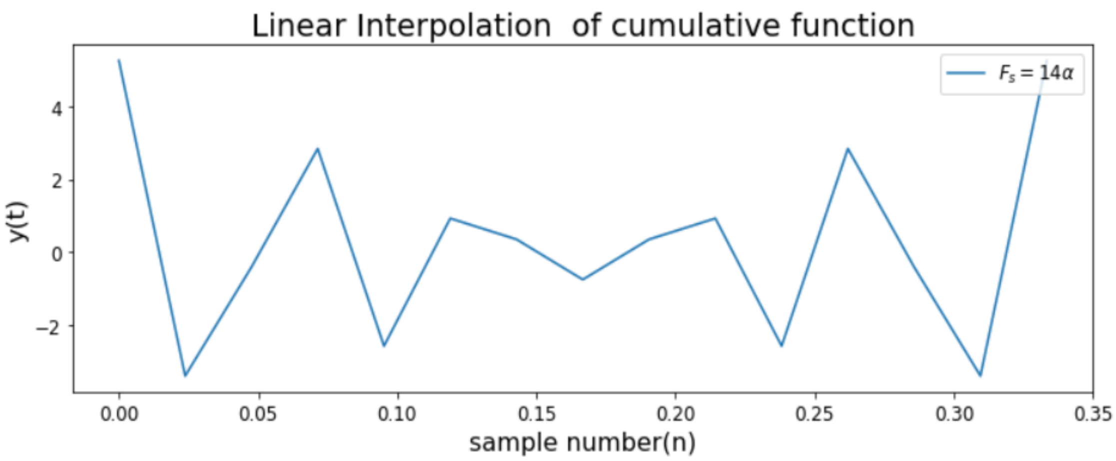
3. The folding frequency to fold 6α to 3α is $\frac{6\alpha+3\alpha}{2} = 9\alpha = 27$



At $F_s = 9\alpha$, the folding frequency is 4.5α. The frequencies 5α, 6α and 10α are folded into 4α, 3α and 1α.

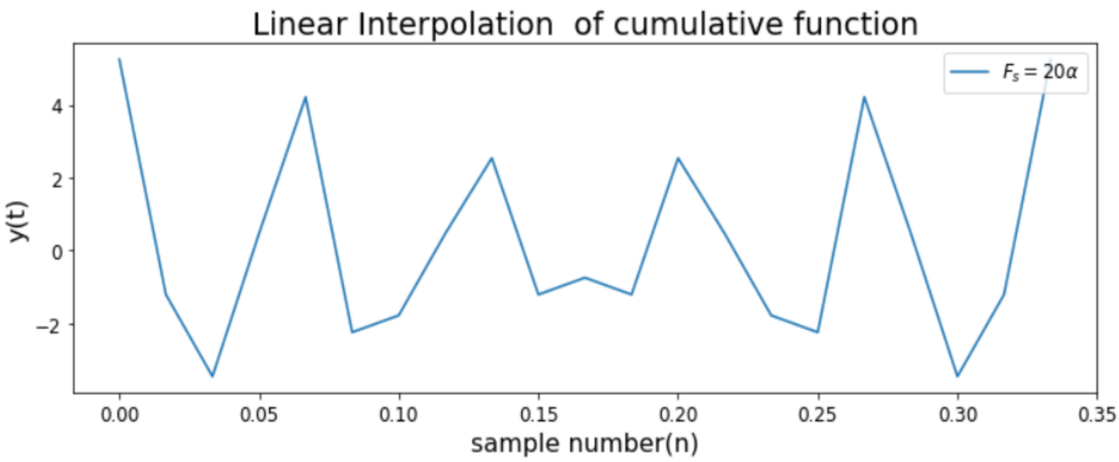
(Linear Interpolation)
(Solution)

1. At $F_s = 14\alpha$, it can be seen that the signal is moderately distorted. But still most of the peaks, local minima and maxima are retained.



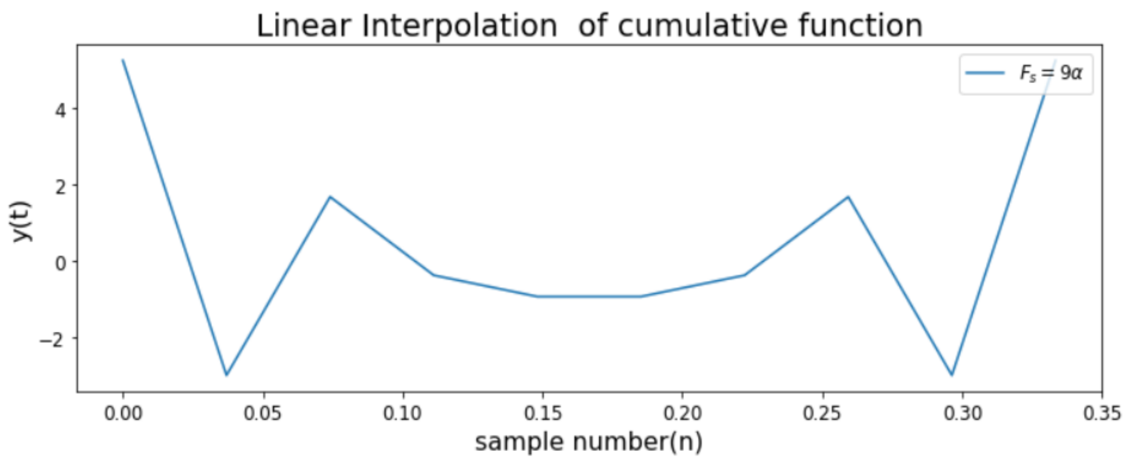
Here only one of the components is folded or aliased. For $F_s = 14\alpha$, folding frequency $= 7\alpha$. Frequency 10α is folded to 4α. But the frequencies 5α and 6α are less than the folding frequency and they are not aliased.

2. At Nyquist Rate $F_s = 20\alpha$, it can be seen that the signal is distorted by a little magnitude when compared to the original signal. Almost all the peaks are retained identically.



There is considerably less distortion compared to the first case. This is because none of the frequency components of the cumulative signal are aliased because of a high sampling frequency (20α).

3. To fold the frequency 6α to 3α, we take sample frequency as $F_s = 9\alpha$. The plotted signal is heavily distorted compared to the original signal. All the peaks in the middle of the signal and also few peaks at the end are also lost.

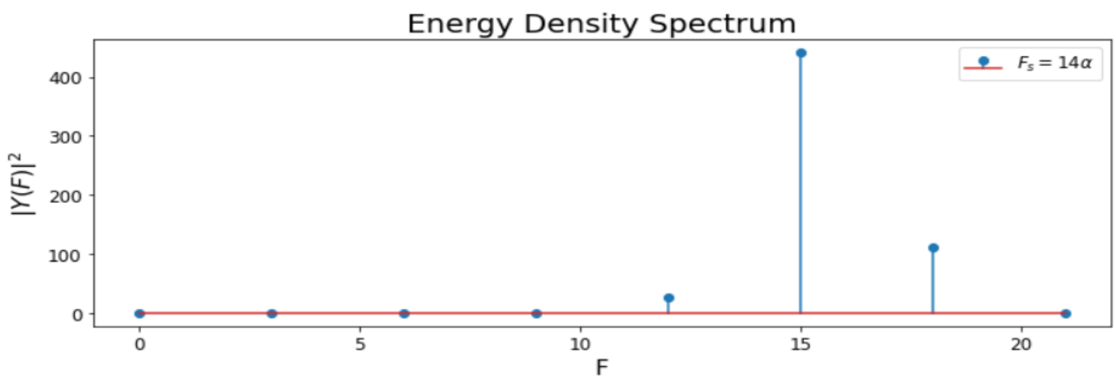


All the components of the cumulative signal are aliased. 5α, 6α and 10α are folded to 4α, 3α and 1α respectively. Hence all the peaks in the middle of the plot, of low magnitude which are caused by high frequency component, are not retained. This causes total distortion in the middle of the plot. Similarly the plot is also distorted at the ends.

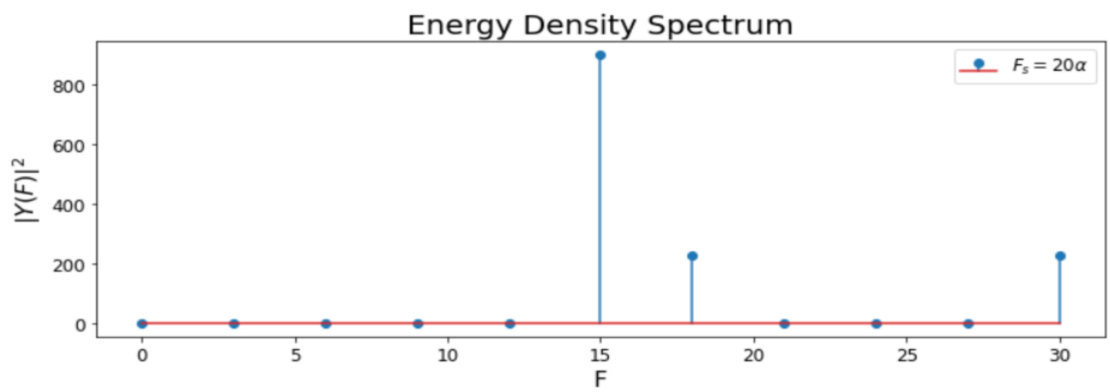
(Energy Density)

(Solution)

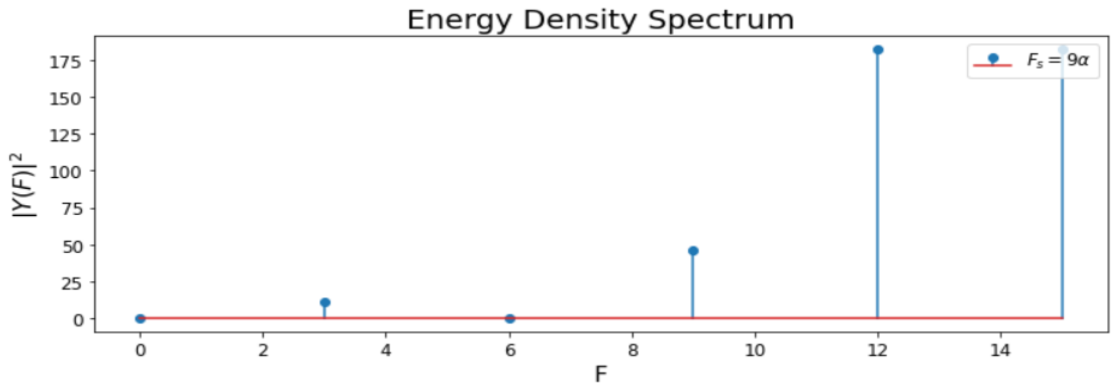
1. At $F_s = 14\alpha$, the folding frequency is 7α. Only 10α gets aliased to 4α.



2. At $F_s = 20\alpha$, the folding frequency is 10α. None of the frequencies get aliased.



3. At $F_s = 9\alpha$, the folding frequency is 4.5α. All of the frequencies get aliased.



Problem 2

(Generating Digital Music)

(Solution)

The frequencies corresponding to "Do Re Mi Fa So La Ti Do" are [261.626, 293.33, 327.03, 348.83, 392.44, 436.04, 490.55, 523.25]. These frequencies are in increasing order. When given ample sample frequency, none of frequency notes are not aliased. But when the sampling frequency is less than the nyquist rate of the signal, some or all of the frequency notes into smaller frequencies. This effect can be observed in the output audio file. When some of the frequencies are folded, the audio file does not have increasing frequency note.
Three sampling frequencies are taken :

1. $F_s = 40000\ \frac{samples}{sec}$. Since none of the frequencies are aliased there is an uniform increasing frequency tone.

2. $F_s = 1500\ \frac{samples}{sec}$. F_s is still slightly above nyquist rate of the signal. Hence we can still hear the increasing tone.

3. $F_s = 800\ \frac{samples}{sec}$. F_s is less than nyquist rate. Here the frequencies, 436.04, 490.55, 523.24 get folded to 363.96, 309.55, 276.76 respectively. Hence after 5^{th} note, the audio has a decreasing note.

Problem 3

(Resampling)

(Solution)

Resampling of the signal is changing the number of samples a given frequency has for a given length.

Downsampling :

During downsampling, some of the data points in the signal are discarded. This reduces the number of the samples in the signal. As a result, some of the data is lost.

Upsampling :

During upsampling, more data points are added based on the current signal. This makes the given signal more smooth. The resulting signal has a higher resolution. The input is read from Track003.wav. Downsampling and Upsampling is done using the resample function.

$\frac{F_s}{2}$, $\frac{F_s}{3}$, $\frac{F_s}{4}$ are the frequencies used to downsample the input file and the outputs are written in prob2down1.wav, prob2down2.wav, prob2down3.wav respectively. F_s* 2 is the sampling frequency taken for upsampling and the output is written in prob2up.wav.

Code Repository

The code, input and output of all the problems is in the following repository :

`https://github.com/KaranTejas/DSP-Lab/tree/main/Experiment2`.