Experiment 7: Sampling and Reconstruction

Aim: This experiment is intended to make the student perform experiments on Sampling of Analog Signal and Reconstruction of the signal from its sampled values using MATLAB.

A – Generation of Sampling Signal and its Properties.

Ideally, sampling of an analog signal is to be done with a train of impulse signals. However, for practical applications, we use pulses of finite durations for sampling analog signals. In this experiment, we will use pulses to sample an analog sinusoidal signal and use filtering to reconstruct the signal.

First, we will study the properties of the sampling pulses, both in time and frequency domains. Follow the steps given below.

a) Generate a periodic pulse signal which will remain ON (take the value "1") for some time and remain OFF (assume the value "0") for the remaining time of the period. Denote the width of the sampling pulse by τ. Note down τ, $1/\tau$, the inter-pulse duration (T) and corresponding frequency (1/T).

b) Obtain the spectrum of the sampling signal and answer the following:

   i. Observe at least 3 major lobes of the spectra. Note the frequency points at which you observe deep nulls in the spectra. Are these frequency values related to (τ) and $1/\tau$, that you measured in (a)? Tabulate in Table 1.

   ii. Increase the width of the sampling pulse, to about twice the previous value. At which frequency point is the deepest dip now? Relate it to the new (τ) and $1/\tau$, and tabulate in Table1.

Table 1: Sampling Signal Parameters

Sl. No	Sampling Pulse width (τ)	Sampling Frequency	$1/\tau$	Spectral Null locations		
1						
2						

iii. Next, observe the distinct spectral peaks within the major lobe. What is the separation between the spectral peaks? How is the separation related to T, measured in Step (a)?

iv. Can you relate this spectrum to the Discrete Fourier Spectrum of the pulse train with pulse width as τ and inter-pulse period as T?

B – Sampling of a Message Signal.

We now sample a 2 KHz sine wave with the sampling pulse sequence, generated in the previous section. Fix the sampling width τ to such that $\tau/T < 0.1$. Fix T such that $1/T > 4k$.

a) To sample the analog sine wave, multiply the sine wave with the pulse signal. Observe the sampled signal. How many samples are appearing in one full cycle of the analog signal?

b) Obtain the spectrum of the sampled signal. Observe individual spectral peaks. Note the frequency values of the spectral peaks. How are these frequency values related to the message frequency and parameters of the sampling pulse train?

C– Recovery of Message Signal from its Samples.

Recovery of the original signal from its samples requires the samples to be filtered by a low pass filter.

a) Filter the sampled signal in the frequency domain by windowing the spectrum to allow only the message signal frequencies through and take the inverse Fourier transform.

   Note: While windowing in frequency, take care w.r.t. the use of "fftshift" command.

   The command to take inverse Fourier transform is the following

   ifft(x)

   where *x* represents the spectrum of the signal.

b) Increase the pulse width to about twice. Observe and comment on the effect of sampling pulse width on the amplitude of the recovered signal.

D – Study of Under Sampling and Aliasing.

You may be aware that sampling of a signal, at a rate not satisfied by Nyquist criterion, results into aliasing and thus spoiling the frequency content of the original message signal. Under these under sampled conditions, the recovered signal from its samples does not resemble the original signal. In this experiment, you will be observing this phenomenon.

a) Generate a 1 KHz sine wave signal and sample it using a 8 KHz sampling signal, keeping the sampling pulse width as mentioned above. Plot and observe the spectrum of the recovered signal. What is frequency corresponding to the spectral peak? Tabulate in Table 2.

Table 2: Under Sampling and Aliasing

Sl. No	Message Frequency	Frequency of the Recovered signal	Remarks on Aliasing effect
1	1Khz		
2	3 Khz		
3	5 Khz		
4	10 Khz		

b) Change the message frequency to 3 KHz and observe the spectrum of the recovered signal. Tabulate the observations in Table 2. Vary the message frequency as shown in Table 2 and observe the spectrum of the recovered signal. Do you see any aliased component in the spectrum? What is the frequency of the aliased component? Also observe the recovered signal obtained using the cut-off frequency for the corresponding message signal.

E –Conclusions:

1. List out your learnings from the experiments