Analysis of a Message Signal using Sampling and Quantization

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Introduction

In communication systems, the message signal is usually transmitted over a channel by first modulating it onto a carrier signal. However, before modulation, the message signal must be sampled and quantized to convert it into a discrete-time signal that can be processed by digital devices. Sampling involves measuring the amplitude of the message signal at regular intervals, while quantization involves approximating the amplitude to a finite set of levels. In this lab report, we will analyze a message signal by sampling and quantizing it..

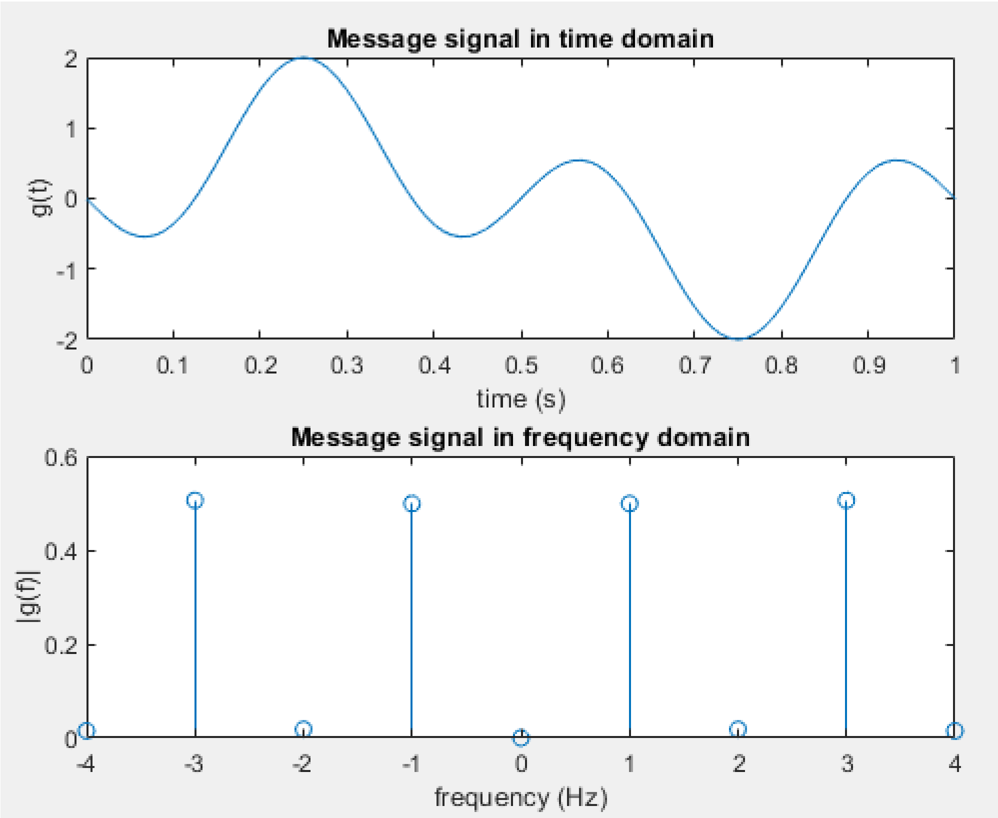
Theory

Sampling is the process of converting a continuous-time signal into a discrete-time signal by measuring its amplitude at regular intervals. The sampling rate is the number of samples taken per second, and it is usually denoted by fs. The Nyquist-Shannon sampling theorem states that to accurately represent a signal, the sampling rate must be at least twice the maximum frequency in the signal. If the sampling rate is less than twice the maximum frequency, aliasing occurs, which results in a distorted signal. An impulse train is a periodic signal consisting of a series of impulses at regular intervals. It is used in sampling to obtain a discrete-time signal from a continuous-time signal. The impulse train is multiplied by the continuous-time signal to obtain a sampled signal. The impulse train has a frequency equal to the sampling rate, i.e., fs. Quantization is the process of approximating a continuous signal to a finite set of levels. The number of levels is determined by the number of bits used to represent the signal. The quantization error is the difference between the original signal and the quantized signal. The quantization error is usually reduced by increasing the number of bits used for quantization.

Plots And Observations

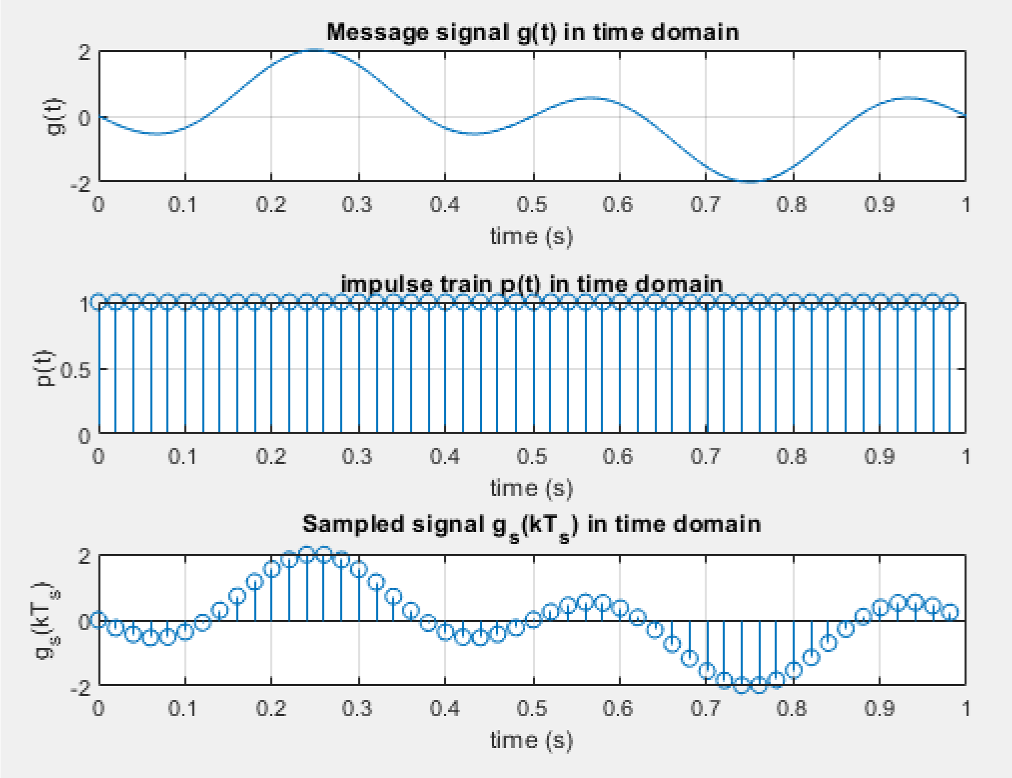
Construct a message/baseband signal g(t) with two sinusoidal components of 1 second duration with frequencies are 1 Hz and 3 Hz, i.e., $g(t) = \sin(2\pi t) - \sin(6\pi t)$. Note, however, that when the signal duration is infinite, the bandwidth of g(t) would be 3 Hz.

(A) Plot a figure having two sub-plots with the message signal g(t) in time domain and frequency domain (use fft() command in Matlab). State your observations.



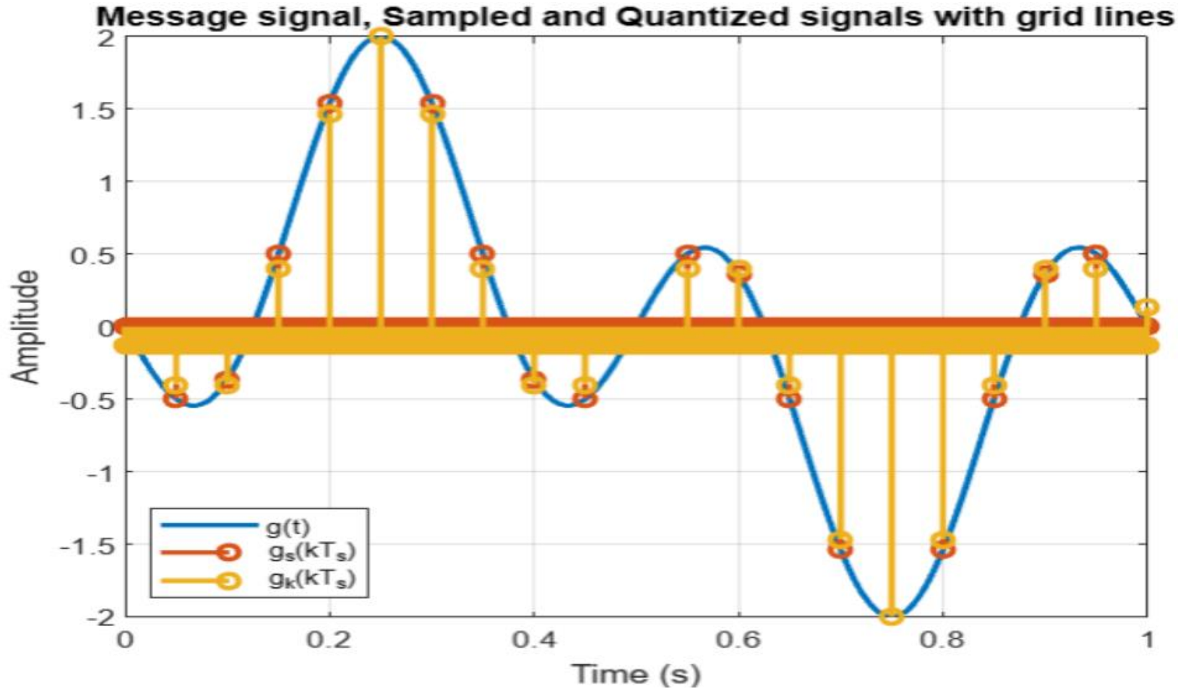
In the time domain plot, we can see that the message signal is a combination of two sinusoidal components with frequencies of 1 Hz and 3 Hz. In the frequency domain plot, we can see that the signal has spectral components at 1 Hz and 3 Hz, as expected. The amplitudes of the spectral components are equal and positive. There are no other significant spectral components present in the signal.

(B) Let the signal gs(kTs) be obtained by multiplying the message signal and an impulse train of frequency fs = 50 Hz. Plot a figure with signals g(t), impulse train (use stem() command in Matlab), and gs(kTs). State your observations.



The amplitude of each impulse is 1, indicating that it is a unit impulse. The impulse train is periodic with a period of 0.02 seconds, which is the sampling interval. This is because the sampling rate is 50 Hz, which means that the signal is being sampled every 0.02 seconds.

(C) Uniformly dividing the peak-to-peak range of the message signal into 16 intervals. Let the amplitude of the signal gs(kTs) be approximated to the midpoint of these 16 intervals, i.e., an amplitude in the range of an interval is quantized to the midpoint of that interval, to obtain ˆg[kTs]. Plot a figure superimposing the signals g(t), gs(kTs) and ˆg[kTs] (use legend() to denote the three signals in Matlab). Also, mark the grid lines at the sampling intervals and quantization levels. State your inferences.



We can observe that the quantized signal ˆg[kTs] follows the shape of the original signal g(t) but has a limited number of possible amplitudes due to quantization. The sampling intervals are evenly spaced at 0.02 seconds, which corresponds to a sampling rate of 50 Hz. The quantization levels are evenly spaced between the minimum and maximum amplitudes of the message signal g(t). The quantization error is the difference between the sampled value of gs(kTs) and its quantized value ˆg[kTs]. This error is present at each sampling instance and can be seen as the difference between the red dots and the green line in the figure.

Conclusion

In this lab report, we analyzed the message signal g(t) by sampling and quantizing it using Matlab. We observed the effect of sampling on the signal by multiplying it with an impulse train of frequency fs=50 Hz. We observed the effect of quantization on the signal by approximating the amplitude of the signal gs(kTs) to the midpoint of 16 intervals. The figures helped us understand the spectrum of the message signal g(t), the effect of sampling, and the effect of quantization on the signal. This analysis is essential in communication systems to ensure that the transmitted signal is accurately represented at the receiver end..