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21AIE315 AI in Speech Processing

LABSHEET 3: Stationary and Non Stationary Signals

Aim

- To understand the difference between stationary and non-stationary signal
- To understand the limitations of Fourier transform in case of non-stationary signals

Stationary v/s non-stationary signals

A signal is said to be stationary if its frequency or spectral contents are not changing with respect to time. The frequency content of a single frequency sine wave will not change with time and hence is an example for stationary signal. Suppose if you change the frequency, then it altogether becomes a new sine wave. Further, the definition of stationarity should not be confused with the time varying amplitude in the time domain as in the case of sine wave. Stationarity is linked to the behavior of the frequency contents of the signal with respect to time.

Generation of single frequency sine wave and its spectrum

The first step is to generate a single frequency sine wave. A sine wave is characterized by its three parameters, namely, amplitude, frequency and phase. To study the concept of stationarity and non-stationarity, the frequency parameter is important and hence we consider maximum amplitude to be 1 and phase to be 0. On a digital machine the sine wave needs to be sampled for plotting or processing and the sampling frequency should be higher than the requirement of baseband sampling theorem. That is, sampling frequency should be more than twice the maximum frequency component for the case of sine wave. For smooth contour of sine wave, it is better to consider the sampling frequency to be much higher than the frequency of the sine wave.

The spectrum of the 10 Hz sine wave generated can be computed using the fast Fourier transform (FFT) command available in the MATLAB. For efficient computation, the next higher binary power is chosen, that is, 1024 point FFT can be used.

Experiment1

I. Generate a 10 Hz sine wave sampled at 1000 Hz sampling frequency and for a duration of 1 sec.
II. Compute the spectrum. The spectrum will be shown only for half portion, since the magnitude spectrum is symmetric with respect to origin

(Hint: take only first 512 samples of magnitude spectrum and plot up on $f = k * fs/N$ where k is the index from 1 to 512, fs the sampling frequency and N the total number of FFT points)

Questions

What is the frequency corresponding to the peak in the spectrum??

Generation of multitone sine wave and its spectrum

On the similar lines described for singletone sine wave, a multitone sine wave can be generated. The only difference is that the number of frequency components are more than one. For better visualization, the sampling frequency should be much higher than the highest frequency component.

Experiment 2

Generate a multitone sine wave made of 10, 50 and 100 Hz frequency components. Plot the magnitude spectrum and check if you are getting peaks at 10, 50 and 100 Hz

Questions

Can you find the frequency components by direct measurement in the time domain?

Is the multitone sine wave a stationary signal? Why?

Generation of non-stationary multitone sine wave and its spectrum

Let us consider a multitone sine wave whose duration is equally divided into four intervals. Let the frequency component of f1 Hz be present in the first interval, then two components of f1 and f2 Hz in the second interval, three components of f1, f2 and f3 Hz for the third interval and finally f1 Hz in the fourth interval. Now if we observe this signal for its entire duration, the frequency components are changing from one interval to the other. Thus such a signal qualifies the definition of non-stationarity and hence is an example for a non-stationary signal. Therefore this signal is more opt to be termed as non-stationary multitone sine wave.

Experiment 3

I. Generate a non-stationary multitone sine wave of duration 1 sec which has 10 Hz component for 0-250 msec, 10 and 50 Hz components for 250-500 msec, 10, 50 and 100 Hz components for 500-750 msec and only 10 Hz component for 750-1000 msec.

II. Generate the spectra

Questions

Can you differentiate this spectra from the one given in experiment 2?

Limitation of Fourier Representation

The final objective of this experiment is to get a feel about the limitation of the Fourier representation in handling the non-stationary signals. Fourier representation also makes an underlying assumption of stationarity for the signal whose spectrum is to be computed. Fourier computation gives information about the different frequency components present in the signal, but not when those frequency contents existed, that is, timing information is missing. The essential information in the non-stationary signal is stored in the time varying spectrum only. Thus just by taking DTFT on the whole signal will not provide any useful information. Hence the limitation of conventional Fourier representation.