# Signal Processing - LAB 5 Report

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We solidify our concepts of Discrete Fourier Transform (DFT or FFT) and then use these concepts to compute linear and circular convolution.

## QUESTION 1

a) The fourier transform is calculated using the formula:

$$X\left(e^{j\omega}\right) = \sum_{-\infty}^{\infty} x[n]e^{-j\omega n}$$

The DTFT of the signal p[n] is found to be -

a) $p[n] = \cos(2\pi n f_0/f_s)$

$$P(e^{j\omega}) = \sum_{n=-\infty}^{\infty} p[n]\, e^{-j\omega n}$$

$$= \sum_{n=-\infty}^{\infty} \cos(2\pi n f_0/f_s)\, e^{-j\omega n}$$

Let $\omega_0 = 2\pi \frac{f_0}{f_s}$

$$\therefore P(e^{j\omega}) = \sum_{n=-\infty}^{\infty} \cos(\omega_0 n)\, e^{-j\omega n}$$

$$= \sum_{n=-\infty}^{\infty} \left(\frac{e^{j\omega_0 n} + e^{-j\omega_0 n}}{2}\right) e^{-j\omega n}$$

$$= \sum_{n=-\infty}^{\infty} \left(\frac{e^{j(\omega_0-\omega)n}}{2} + \sum_{n=-\infty}^{\infty} \frac{e^{-j(\omega_0+\omega)n}}{2}\right)$$

$$= \underline{\delta[\omega - \omega_0] + \delta[\omega + \omega_0]}$$

b) It is apparent from the DTFT of p[n] that the location of the impulses are at $+w_0$ and $-w_0$ respectively.

Since $w_0 = 2 * pi * f_0/f_s$

we can say that the impulses differ by 4*pi

c) The Fourier transform of x[n] is calculated using the multiplication property of DTFT

c) $x[n] = p[n] \times w[n]$.

$$X(e^{j\omega}) = \int_{-\infty}^{\infty} P(k)\, W(n-k)\, dk.$$

Multiplication of two signals, causes a convolution in the DTFT domain.

$\therefore$ DTFT of $x[n]$ will be the convolution of the DTFT's of $p[n]$ and $w[n]$.

d) The plots are consistent with our findings.

e) The spectrum becomes more accurate as the value of L increases, becoming more condensed. Thus, the frequency resolution increases as the length of the signal (L) increases.

i) The 3 strongest frequencies in the audio signal are found by finding the corresponding x-values

Thus, from the plot we see that the highest frequencies are at 400, 240 and 1040.

# QUESTION 2

a) The gaussian random sequence is plotted by generating 10 values from a gaussian distribution having a mean of 1 and a variance of 1 also.

b) The commands *conv* and *cconv* perform linear and circular convolution of the two signals.

c) We pad the respective signals with zero, perform DFT on them, multiply their DFT spectrums and then perform inverse DFT on the product of the multiplication to get the linear and circular convolution outputs.

For linear convolution, we take the size of the DFT and inverse DFT as (N1+N2-1)

d) The two methods of finding the output of convolution gives the same results.

# QUESTION 3

a) The DFT's of the given signals are found using the *fft* function in MATLAB.

The low and high frequencies are very apparent in the DFT magnitude plots.