**Indian Institute of Space Science and Technology**
**AV336 - Digital Signal Processing Lab**
**Department of Avionics**

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## Labsheet 3

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1. Review what causal and non-causal discrete time impulse responses are. Using Matlab plot examples of non-causal and causal discrete time impulse responses (2 each).

2. Let $h[n]$ as defined below be the impulse response of a discrete time LTI system

$$h[n] \quad = \quad \begin{cases} n, \text{ for } n \in \{0, 1, 2, \ldots, 10\}, \\ 0, \text{ otherwise.} \end{cases}$$

   Using Matlab, plot the frequency response of this system (plot the magnitude and phase spectra separately). Note that the frequency response is the DTFT which is a continuous function of the frequency $\omega$. Therefore, a sufficiently "smooth" discretization of $\omega$ is needed for obtaining these plots. Observe whether the frequency responses are periodic with $\omega$ or not.

3. Write a Matlab function to plot the frequency response (magnitude and phase) corresponding to any $h[n]$, rather than the specific case above. The function should take $h[n]$ and two variables "dbscale", "actualfreq" as input. The function should produce the magnitude and phase response as output. If the "dbscale" variable is 1 then the magnitude should be plotted in decibels. If the "actualfreq" variable is not $-1$, then the $\omega$ axis should be plotted in actual frequencies by interpreting the value of the "actualfreq" variable as the sampling frequency used to produce the discrete time signal (i.e., the time duration between two samples is $1/actualfreq$). Test this function with example inputs (you are free to choose non-trivial inputs) and demonstrate that your implementation is correct. The inputs should be chosen carefully to test the function.

4. We know that if a discrete time LTI system has an impulse response $h[n]$ and if the input to the system is $x[n]$, then the output (defined as $y[n]$) is given by the discrete time convolution of $x[n]$ and $h[n]$.

   (a) Write a Matlab function "discreteTimeConvolve" that takes as inputs the impulse response and the input signal and produces the output signal as output. Please note that this function should not use any inbuilt Matlab functions to do convolution but rather implement convolution using basic array operations.

   (b) Now find out whether any inbuilt Matlab function can be used to directly implement convolution. Demonstrate the use of this function using 3 examples.

5. A discrete time LTI system can also be specified by a constant coefficient difference equation as follows:

$$y[n] = \sum_{k=0}^{N} a_k x[n-k] + \sum_{l=1}^{M} b_l y[n-l].$$

(a) Implement a Matlab function "discreteTimeCCDE" that takes as input the set of $N+1$ coefficients ($a_k$) and $M$ coefficients ($b_l$) and an input signal $x[n]$ and produces as output the signal $y[n]$. Please note that any initial conditions can be taken as input or assumed. Do not use any inbuilt Matlab functions for this part.

(b) Now find out whether any inbuilt Matlab function can be used to directly the above operation. Demonstrate the use of this function using 3 examples. (Hint: we have seen this in class when we studied IIR filters.)

6. In this task, you will explore one of the most important properties of the DTFT. Suppose $h[n]$ is the impulse response of a discrete time LTI system. The LTI system has output $y[n]$ when $x[n]$ is the input. Let $H(\omega), X(\omega)$ and $Y(\omega)$ be the DTFTs of $h[n], x[n]$, and $y[n]$. We know that $Y(\omega) = H(\omega)X(\omega)$.

   (a) Write a Matlab function to compute the DTFT of a signal; note that you have already done this in (2) in this labsheet. The DTFT that is being computed is a suitably discretized version of the actual DTFT (defined for the continuous $\omega$).

   (b) Using the above function compute $H(\omega)$ and $X(\omega)$ and their product $Y(\omega)$.

   (c) Compute $y[n]$ by taking the inverse DTFT (think about how you will implement this on your computer; are there inbuilt Matlab functions that can help you implement this.)

   (d) Compare the $y[n]$ that you have obtained with what is obtained via directly convolving $x[n]$ and $h[n]$. Are there any differences? If there are, then why do such differences arise.