The LNM Institute of Information Technology
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Experiment No. # 4
LTI System Characterization II: Circular convolution and DFT makes Fourier Transform pair

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1) **Objectives:**
   a) Circular convolution and DFT Multiplication for two sequences.
   b) Simulink based circular convolution.
2) **Software used:**
   a) MATLAB.

A. *Pre-Lab*

a) Read about circular convolution.
b) practice simulink.

I. CIRCULAR CONVOLUTION ⇔ DFT

A. ***Theory***

1) J. Proakis and D. Manolakis, Digital signal processing: principles, algorithms, and applications

B. ***Procedure***

1) Circular Convolution: Write a MATLAB function myCirConvMat.m that takes in the impulse response $h(n)$ of an LSI system and the length of input sequence $x(n)$ and provides in output the matrix representing the circular convolution operator H. Compute and plot the convolution results for the following:

$$h_1(n) = \{2, 1, 2, 1\}$$

$$x_1(n) = \{1, 2, 3, 4\}$$

$$x_2(n) = 0.5^n$$

Here $n = 0, 1, \cdots 9$ samples.
The circular concolution sum for a system with $h(n)$ system response and $x(n)$ input is given by (both paded with zeros to make the length equal of both the sequences).

$$y(n) = \sum_{i=0}^{N-1} h(i) \cdot x((n-i))_N$$

Where N, the sequence length is greater or equal to length of the larger sequence and taken as multiple of 2. $N = 2^i \qquad i = 2, 3, 4....$
Also, $x((n-i))_N$ represents the index '$((n-i)\ modulo\ N)$ = $N - i + n$'.

2) Change of basis: For an LSI system, let the impulse response be given by $h(n) = h(0), \cdots h(7)$. The 8-point input to this system is a finite duration sequence $x(n) = x(0) \cdots x(7)$.
Now, to verify Circular Convolution $\Leftrightarrow$ DFT, perform the following steps.
   a) Use your myCirConvMat.m to find circular convolution of $h(n)$ and $x(n)$ given by $y(n)$.
   b) Use myDFT function to generate 8-Point DFT matrix.
   c) Find out 8-point DFT of sequence $h(n)$ and $x(n)$ given by $H(k)$ and $X(k)$.
   d) Multiply both above DFT sequence point by point and generate $Y(k) = H(k) \cdot X(k)$.
   e) Find inverse DFT od $Y(k)$ using myDFT function and compare the result with the first step.

   Let's verify it using matrix multiplication.
   a) Use your myCirConvMat.m to find convolution matrix H.
   b) Use myDFT function to generate 8-Point DFT matrix D_8.
   c) Find out 8-point DFT of sequence$x(n)$ given by $X_F(k)$.
   d) Calculate $H_F = D_8 \cdot H \cdot D_8^{-1}$. Is this matrix Diagonal? Compute $Y_F = H_F \cdot X_F$. Find $y = D_8^{-1} \cdot Y_F$
   e) Compare the above result with the circular convolution of $h(n)$ and $x(n)$.

3) **Observation:**
   a) Generate Circular Convolution matrix H.
   b) Perform circular convolution code and compare your results with MATLAB built in command for circular convolution.
   c) Generate myIDFT using myDFT function. Verify 'Circular convolution $\Leftrightarrow$ DFT multiplication are fourier transform pair' using first five steps of change of basis section.
   d) Verify the above answers using the matrix multiplication steps given in the change of basis section.
   e) Repeat the experiment in simulink.
4) **Conclusion:** Conclude the experiment.

II. Convolution in Simulink

1) Open simulink and create a model file with .slx extension.

2) Read input data $x = [1, 2, 3, 4]$ through command window.

3) Take channel coefficents $h = [2, 1, 2, 1]$.

4) Perform the circular convolution using matlab function in simulink.

5) Repeat all the 'Procedure' steps and recreate all functional blocks into simulink.

Well Done
