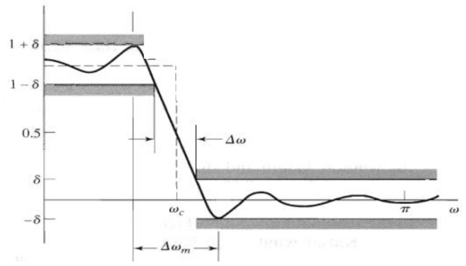
AV343 – Miniproject 1,
Department of Avionics,
Indian Institute of Space Science and Technology.

Useful information for filter design



Typical amplitude response (window)

Type of Window	Peak Side-Lobe Amplitude (Relative)	Approximate Width of Main Lobe	Peak Approximation Error, $20\log_{10}\delta$ (dB)
Rectangular	−13	$4\pi/(M+1)$	−21
Bartlett	−25	$8\pi/M$	−25
Hann	−31	$8\pi/M$	−44
Hamming	−41	$8\pi/M$	−53
Blackman	−57	$12\pi/M$	−74

Window design parameters

Kaiser window design formulae

$$\Delta\omega = \omega_s - \omega_p \quad A = -20log_{10}\delta$$

$$M = \frac{A-8}{2.285\Delta\omega}$$

$$\beta = \begin{cases} 0.1102(A-8.7), \text{ if } A > 50, \\ 0.5842(A-21)^{0.4} + 0.07886(A-21), \text{ if } 21 \le A \le 50, \\ 0.0, \text{ if } A < 21. \end{cases}$$

Useful Matlab inbuilt functions: conv, filter, fft, fftshift, ifft, freqz, hamming, hanning, blackman, kaiser, firpm, fir1, fir2, firls, buttord, butter, residuez.

Task 1: Generation of a signal with "essentially" low pass nature.

Your first task is to generate a discrete time real valued signal x[n] which has an "essentially" low pass nature. Suppose X(w) is the DTFT of x[n] (assume it exists). The "essential" low pass nature property for x[n] is defined as consisting of all the following properties (defined for $-\pi \le w \le \pi$)

- $|X(w)| \le 0.001$ for $|w| \ge 0.1\pi$,
- $|X(w)| \le 0.25$ for $|w| \ge 0.075\pi$, and $|w| < 0.1\pi$,
- $0.25 \le |X(w)| \le 0.5$ for $|w| \ge 0.05\pi$, and $|w| < 0.075\pi$,
- $0.5 < |X(w)| \le 1$ for $|w| < 0.05\pi$.

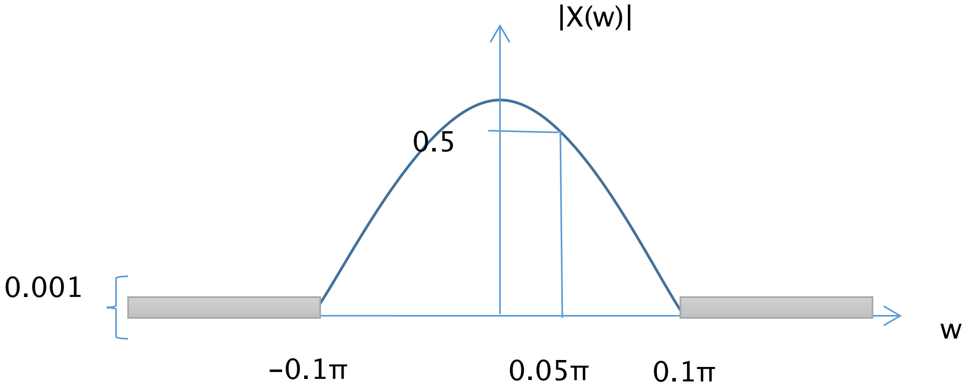
1. Using Matlab generate any "essentially" low pass signal x[n] which has a finite extent of M (i.e., x[n] is 0 for $n \le -1$ and $n \ge M$). You can choose M.

Task 2: Visualizing the "essentially" low pass nature of x[n].

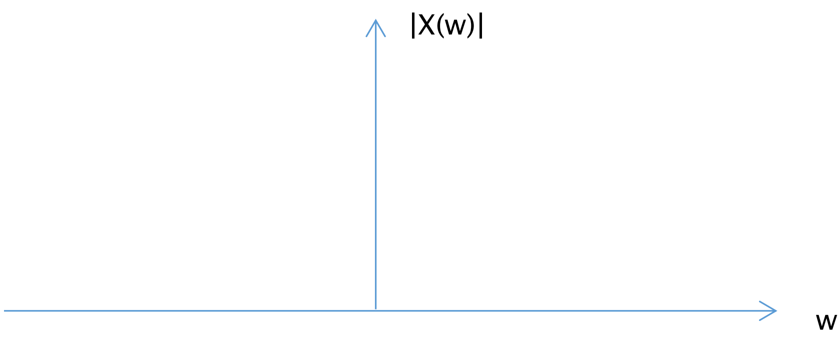
For the x[n] that you have obtained in Task 1, plot the magnitude of the DTFT X(w) in decibels, for $-\pi \le w \le \pi$ and the phase of the DTFT X(w) (wrapped between [$-\pi$, π], for $-\pi \le w \le \pi$.

Task 3: Understanding the operation of a scrambler.

A possible magnitude plot (in absolute scale) of the X(w) would be like in the diagram shown below.



- An essentially low pass signal can be thought of as being obtained by sampling spoken voice appropriately.
- In order to communicate this voice securely over phone lines which may be subjected to *eavesdropping*, a simple technique is to do *scrambling*.
- The process of scrambling of the above signal is defined to be sequence of steps applied to the DTFT X(w) of an essentially low pass signal:
  1. Define $X_1(w) = X(w)$ for $0 < w \leq 0.1\pi$ and $X_1(w) = 0$ otherwise.
  2. Define $X_2(w) = X(w)$ for $-0.1\pi \leq w \leq 0$ and $X_2(w) = 0$ otherwise.
  3. Define $X_3(w) = X_1(0.1\pi + w)$ and $X_4(w) = X_2(-0.1\pi + w)$.
  4. Define $X_{scrambled}(w) = X_3(w) + X_4(w)$
- Understand what the scrambling operation is – think about how the magnitude and phase of X(w) is affected when the scrambling operation is done.
- Draw a rough magnitude plot (in absolute scale) of $X_{scrambled}(w)$ for the essentially low pass signal x[n] that you have generated below. Please note that this need not be done in Matlab. Please plot for $-\pi \leq w \leq \pi$.



Task 4: Understanding an "approximate" implementation of the scrambler

- Consider the block diagram shown in the next page.
- Do you think it is possible to design the blocks (A), (B), (C) and (D) so that an "approximate" implementation of the scrambling operation can be obtained?
- Write down the functions of blocks (A), (B), (C), and (D) for an "approximate"

implementation of the scrambling operation.

- Hint: Think about what is happening to the signal x[n] at each point in the block diagram, using the blocks whose functionality is already shown.
- Info: The multiplier block has two discrete time signals as inputs a[n] and b[n] and puts out c[n] = a[n] x b[n] for every n.

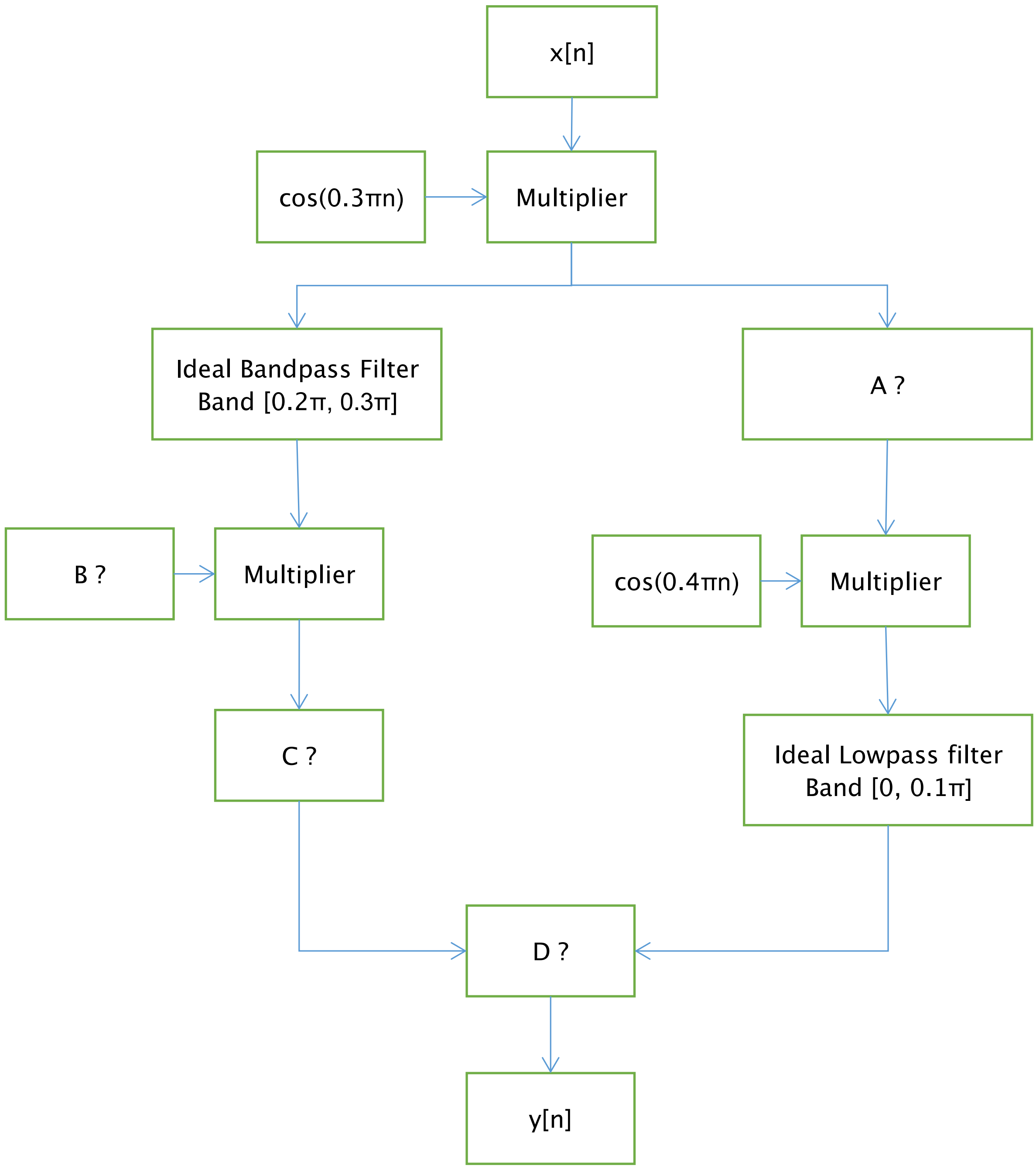


Fig: Block diagram of a possible implementation of a scrambler

Task 5: Plan for implementation of the scrambler

- In this task you have to plan the approximate implementation of the scrambling system shown in the block diagram.
- Note that for planning the scrambling system you have to fully specify what each block in the block diagram does.
- Furthermore, any ideal blocks need to be replaced by realizable blocks (e.g., actual filters).
- For every block shown in the block diagram, you have to first write down the input-output relationship (in words).
- If the ideal behaviour of a particular block can be implemented in Matlab without any change, then you should write down the input output relationship.
- If the ideal behaviour of a particular block (such as a filter) needs to be changed, then you should specify the filter design requirements ($H_d(w)$) here for that filter.
- Once you have specified the filter design requirements, then please note down how that filter would be designed and realized in Matlab. You can use any filter design technique that we have learned in class in order to do this.
- Please use the inbuilt function firpm (which we studied in Labsheet 8) to design any bandpass filters that you need. Consult the Matlab documentation in order to see how you can use firpm to obtain bandpass filters.

Task 6: Implementation of the system in Matlab

- In this task you will implement the system that you have designed in Task 5 in Matlab.
- The system should take in x[n] as input and return y[n], which is obtained by applying the operations as indicated in the block diagram on x[n].
- Plot the magnitude (in absolute scale) of the DTFT Y(w) of y[n] In Matlab and compare with the magnitude plot of the DTFT X(w) on the same figure.
- Also make a rough plot of your results, i.e., the magnitude of DTFTs X(w) and Y(w) (in absolute scale), on the axes shown below. Please plot for $-\pi \le w \le \pi$.