# Communication Systems Lab

## Lab 2: Up/Down-sampling and Filtering

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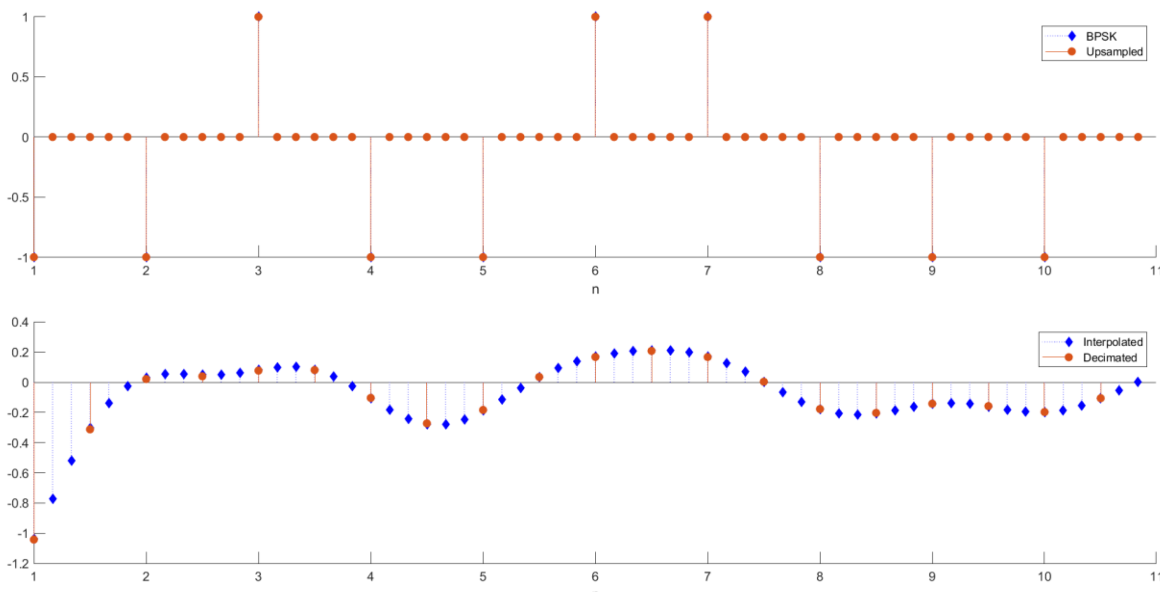
1. A successful transmission with up/down-sampling
   A. Explain how you choose the interpolation and decimator filters based on the upsampling factor $L$ and the downsampling factor $M$.

      Since we upsample the input signal by $L$, the frequency band shrinks from $\pi$ to $\pi/L$. Hence, we use a lowpass filter with normalized cutoff frequency $1/L$. Furthermore, when we downsample the signal, the frequency band will extend by $M$. To prevent aliasing, we again use a lowpass filter with normalized cutoff frequency $1/M$. (Here we use the `lowpass` function.)

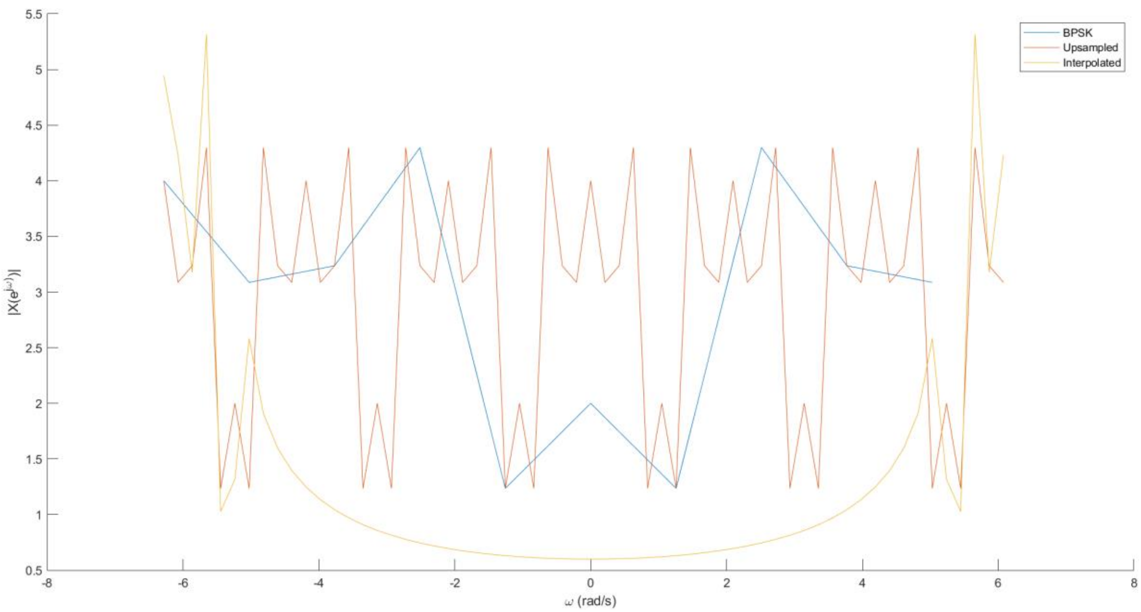
   B. In the same figure, compare the time domain signal at b, c, d, and f, as marked in Fig. 1. Please align signals and remember to add the legend.



C. Describe the figure obtained in B. What do you observe?

When we upsample the signal, we add more points to adjacent values. When the signal gets decimated, only a portion of the points were chosen.

D. In the same figure, compare the frequency domain signal at b, c, and d, as marked in Fig. 1. Please have the X-axis in the range $[-2\pi, 2\pi]$ and remember to add the legend. (hint: `fftshift`)




E. Describe the figure obtained in D. What do you observe?

When we upsample the signal, the frequency band get closer together. When we downsample the signal, the midband signal disappeared.

F. Repeat the procedure with 1000 bits, what is the bit error rate you obtain?

When we repeat the procedure with 1000 bits using the `lowpass` filter function, our error rate goes to 0. However, if we use `fir1` function, we get an error rate of nearly 0.5.

2. Aliasing in down-sampling with or without the decimator filter

A. In the same figure, compare the time domain signal at **b**, **d**, **e**, **f**, and **h**, as marked in Fig. 2. As before, please align signals and remember to add the legend.

B. Describe the figure obtained in A. What do you observe?

C. In the same figure, compare the frequency domain signal at **b**, **d**, **e**, **f**, and **h**, as marked in Fig. 2. As before, please have the X-axis in the range $[-2\pi, 2\pi]$.

D. Describe the figure obtained in C. What do you observe?

E. With this bitstream alternating between 1 & 0, how many bit errors occur when the decimator is employed vs. not employed?

F. Similar to A, repeat the simulation with a new bitstream:
[1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0] (Alternate between 111 and 000).
In the same figure, compare the time domain signal at **b**, **d**, **e**, **f**, and **h**, as marked in Fig. 2.

G. Describe the figure obtained in F. What do you observe?

H. With this bitstream alternating between 111 & 000, how many bit errors occur when the decimator is employed vs. not employed?

3. Square Root Raised Cosine (RRC) filter

A. Plot the interpolation filter you use in both time and frequency domain.

B. In the same figure, compare the time domain signal at **b**, **d**, **e**, and **f**, as marked in Fig. 1. Please align signals and remember to add the legend.

C. Describe the figure obtained in B. What do you observe? How is it different from the figure obtained in Part 1 with idealized lowpass filters?

D. How many bit errors occur when employing RRC filters with $\alpha = 0.5$?