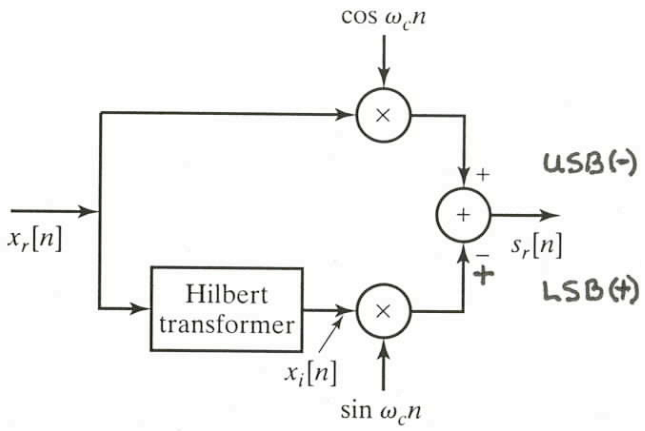
Single Sideband Generation

A. Implement the block diagram shown below (Figure 12.11a in [1]) and demonstrate the successful generation of both upper and lower single sideband signals.



B. Let $x_r(n)$ be 1024 points in length and consist of three low frequency sinusoids ($f_1 = 0.05$, $f_2 = 0.075$, and $f_3 = 0.10$ cycles/sample) separated in level by 10 dB ($A_1 > A_2 > A_3$) and let the carrier frequency be mid-band ($f_c = 0.25$ cycles/sample). Design a 64-point FIR Hilbert transformer for use in the single sideband generator.

C. Plot the impulse response and transfer function (dB magnitude and phase) of the Hilbert transformer. In addition, blow up the phase plot in the vicinity of f = 0 cycles/sample (e.g. plot f = -0.01 to f = +0.01 cycles/sample) so you can illustrate the phase discontinuity.

D. Plot FFTs (dB magnitude only; no need for phase plots) at each stage of the system from input through output including FFTs of the real signals $x_r(n)$, $x_r'(n)$, $x_i(n)$, $x_r'(n)\cos(2\pi f_c n)$, $x_i(n)\sin(2\pi f_c n)$, and $s_r(n)$ (both USB and LSB). Also, plot the FFTs of the complex signals $x(n) = x_r'(n) + j\, x_i(n)$ and $s(n) = x(n)\exp(+j2\pi f_c n)$. Use a good window function with your FFTs and use NFFT = 256. Just a single FFT is needed so there will be additional unused points in your various time series.

Note:

(1) Make sure that the time delays through the upper and lower paths in the block diagram are identical. One way to do this is to insert a 64-point FIR all-pass filter (or low-pass filter which passes the three sinusoidal components of interest) in the upper path to match the time delay through the Hilbert transformer. The output of this filter is $x_r'(n)$. Plot the impulse response and transfer function (dB magnitude and phase) of this upper path filter.

(2) You should throw away the first 64 points from all time series prior to doing any FFTs. This is due to the initial transient effects at the output of the FIR filters in both the upper and lower paths of the block diagram.

[1] A. Oppenheim and R. Schafer. Discrete-Time Signal Processing. Prentice-Hall (2010, 3rd Edition).