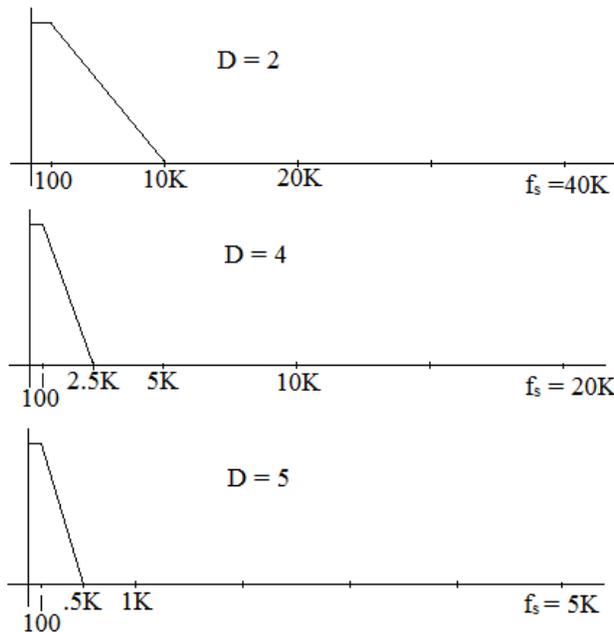


7.7 Consider a signal which has a pass band of 0 to 100 Hz. The sample frequency is 40,000 Hz and we wish to reduce this sample frequency to just 1000 Hz, or a factor of $D = 40$. We want a decimator with a pass band ripple of $r_p = 0.01$ and a stop band ripple of $r_s = 0.001$. Determine the filter specifications if the decimator is implemented as a cascade of 2-4-5 using Parks-McClellan filters.

Solution

The pass band will be 0 to 100 Hz for all three filters. For the first filter when $D = 2$ the stop band will go from 10 KHz to 20 KHz. The new sample frequency after down sampling will be 20 KHz. For the second filter with $D = 4$, the stop band will go from 2.5 KHz to 10 KHz. The new sample frequency after down sampling will be 5 KHz. For the final filter with $D = 5$ the stop band will go from 500 Hz to 2.5 KHz.



Since the three filters are cascaded the ripple numbers multiply to form the ripple for the final filter. For the pass band we have $(1 - R_{p1})(1 - R_{p2})(1 - R_{p3}) = (1 - R_{p_{final}})$. Since the ripple is small compared to 1 and if we make $R_{p1} = R_{p2} = R_{p3} = R_p$ then $R_{p_{final}} \approx 3R_p$. For this case we want $3R_p < 0.01$ or $R_p < 0.0033$.

For the stop band we have $R_{st1} \times R_{st2} \times R_{st3} = R_{st_{final}}$. If we make $R_{st1} = R_{st2} = R_{st3} = R_{st}$ then $R_{st_{final}} = R_{st}^{1/3}$. For this case we want $R_{st} = 0.001^{1/3}$ making $R_{st} = 0.1$.

However, we must also take into account that the stop band ripple in each case can be folded back into the pass band by aliasing. Thus we want $R_p + R_{st} < 0.0033$. making $R_p = 0.001$ and $R_{st} = 0.002$ will satisfy these requirements.

7.10. The upsample function in MATLAB® inserts zeros between samples to get a signal which is sampled at a higher rate. Suppose I have a sinusoid that has a frequency of 1000 Hz that is sampled at 5000 Hz. Predict what the spectrum will look like if the upsample

function is applied to the signal to (a) raise the sample frequency by a factor of 2 and (b) raise the sample frequency by a factor of 3. Verify your prediction using MATLAB®.

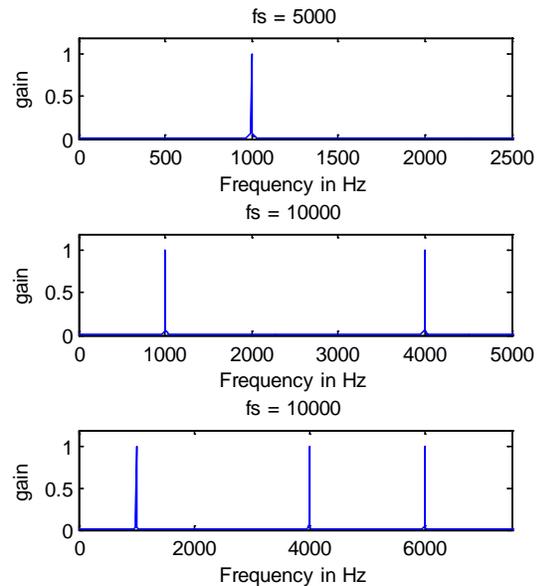
Solution

A 1000 Hz signal sampled at 5000 Hz will have its first two aliases at 4000 Hz and 6000 Hz. If the sample frequency is double the alias at 4000 Hz will become part of the spectrum below the Nyquist frequency. If the sample frequency is tripled the 4000 Hz and the 6000 Hz aliases will become part of the spectrum below the Nyquist frequency.

```

fs = 5000;T = 1/fs;
fsig = 1000;
t = 0:T:.4;
x = sin(2*pi*fsig*t);
yup2 = upsample(x, 2);
yup3 = upsample(x, 3);
figure(1);clf;
subplot(3, 1, 1);
xfft = fft(x);
xfft = xfft/max(abs(xfft));
k = 0:length(x)-1;
plot(k*fs/length(x),
abs(xfft)/max(abs(xfft)));
axis([0 fs/2 0 1.2]);
xlabel('Frequency in Hz');
ylabel('gain');
title(['fs = ' num2str(fs)]);
%
subplot(3, 1, 2);
yup2fft = fft(yup2);
yup2fft = yup2fft/max(abs(yup2fft));
k = 0:length(yup2)-1;
plot(k*2*fs/length(yup2),
abs(yup2fft)/max(abs(yup2fft)));
axis([0 fs 0 1.2]);
xlabel('Frequency in Hz');
ylabel('gain');
title(['fs = ' num2str(2*fs)]);
%
subplot(3, 1, 3);
yup3fft = fft(yup3);
yup3fft = yup3fft/max(abs(yup3fft));
k = 0:length(yup3)-1;
plot(k*2*fs/length(yup3),
abs(yup3fft)/max(abs(yup3fft)));
axis([0 fs 0 1.2]);
xlabel('Frequency in Hz');
ylabel('gain');
title(['fs = ' num2str(2*fs)]);

```



7.13 Suppose you have two identical signals which are limited to a small band of frequencies around 1000 Hz. The first signal is sampled at 11025 Hz and the second is sampled at 22050 Hz. If we up-sample both signals to 44100 Hz what will be the difference in the frequency characteristics of the two.

Solution

The first signal sampled at 11025 will have frequency components at 1000 Hz, 10025 Hz, 12025 Hz, and 21050 Hz. The second signal sampled at 22050 will have components at 1000 Hz. And 21050 Hz.

7.14 A signal which is limited in frequency to the band from 0 to 4 KHz is sampled at 11,025 Hz. If a 8-bit A/D converter is being used and we want to up-sample this signal to 22,050 Hz, what are reasonable specifications for the interpolation filter if we want to use a Parks-McClellan filter.

Solution

The pass band will go from 0 to 4 KHz. The stop band will begin at $11025 - 4000 = 7025$ Hz. Since we have an 8-bit A/D converter the quantization noise is at roughly -48 dB which corresponds to 0.004. A reasonable number for the pass and stop band ripple would be 0.002.