Applied Signal Processing

Computer studio session 2:

FIR and IIR filter design

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Introduction

In this session you will use MATLAB to design IIR and FIR filters and compare them.

Problems

An analog signal $x(t)$ consists of two components $x_1(t)$ and $x_2(t)$. The spectral characteristics of $x(t)$ is shown in Figure 1. The signal $x(t)$ is band-limited to 40 kHz and is sampled at a rate of 100 kHz to yield the sequence $x(n)$. It is desired to suppress the signal $x_2(t)$ by filtering $x(n)$ through a low pass filter. The allowable distortion on $|X_1(F)|$ is $\pm 2\% (\delta_1 = 0.02)$ over the range $0 \le F \le 15kHz$. Above 20 kHz the filter should have an attenuation of at least 40 dB ($\delta_2 = 0.01$).

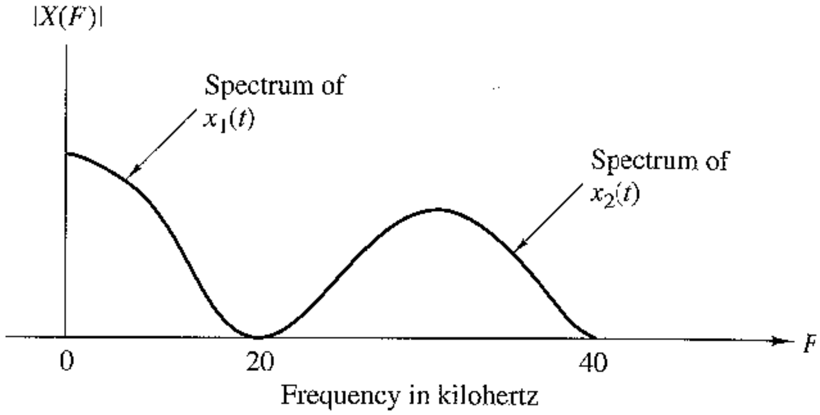

Figure 1: Spectrum of signal $x(t)$

1. Use the Parks-McClellan optimal min-max filter design to find a minimum-order linear phase FIR filter which meet the given specification. From the plot of the magnitude characteristics check that your design fulfill the specifications.

2. Use the same filter order as designed in 1) and use the window technique with Hamming and Chebyshev windows. Compare the frequency response characteristics of the designed filter and the filter in 1). Can you make them meet the specs?

3. Design a minimum order elliptic filter that meets the given amplitude specifications and compare with the filters obtained in 1) and 2).

4. Compare the complexity of implementation of the FIR filter designed in 1) with the elliptic IIR filter. Use total storage requirement and number of multiplications required for each output sample as a measures of complexity.

Matlab issues

- When designing digital filters in MATLAB it is important to know that all frequency specifications are given relative to the Nyquist frequency, i.e. half the sampling frequency. As an example assume a filter with cut-off frequency of 6 kHz is to be designed and the sampling rate is 20 kHz. Then the relative frequency used in MATLAB is $f_c = 2 * 6/20$.

- For solving 1) use Matlab command `firpm`. Note that you can supply a separate weighting for the passband and the stop band respectively. This can be used to obtain different ripple sizes for different frequency regions. See the help text in MATLAB for further information.

- To plot the frequency response for a FIR filter h you can use the commands

```
Fs = 100; % Sampling frequency NN = 2^10;
F = (0:NN-1)/NN*Fs;
H = abs([fft(h,NN)]);
plot(F,20*log10(H)); % Zoom in plot to check specifications
```

- For solving 2)use command `fir1`.

- For solving 3) use command `ellip`.

- To plot the response for an IIR filter (using the same frequency grid as above) use

```
H5 = freqz(b,a,F*2*pi/Fs);
```

  Where b is the numerator coefficients and a the denominator coefficients of the IIR filter.