EE-556 Fall 2015 DSP Take-Home Final

(A Chance to Really Shine and Impress your Friends and Family)

A Dual Tone Multiple Frequency (DTMF) key pad on your telephone uses frequencies 697, 770, 852, and 941 Hz (low band) for the rows of the pad and 1209, 1336, 1477, and 1633 Hz for the columns of the pad (see figure below). We are to design a DTMF signal detector.

1. The input signal is sampled at 8600 Hz with an 8-bit ADC.
2. Since all the frequencies are below the quarter sample rate, 2150Hz, we first pass the signal through a low pass filter and down-sample 2-to-1 to reduce the workload for the next filters.

1. The down sampled signal is separated into two bands, the Low and High Band, by a pair of bandpass filters.
2. The outputs of these two filters are again down sampled 4-to-1 to further reduce the workload for the next filters.
3. The reduced sample rate may violate the Nyquist criterion for the tones in the two down-sampled time series and the tones may appear at their aliased spectral positions.
4. The down sampled time series are presented to 4-band-pass filters centered on their four possible aliased tone frequencies: the output of these filters are compared and the two signal components with the largest amplitude will define the key stroke.

 



1. Design an elliptic filter for the half band low pass filter that satisfies the following specifications.

Sample Rate: 8.6 kHz

Passband: Frequencies 0-1650 Hz, Ripple 0.02 dB

Stopband: Frequencies 2670-4300 Hz, Ripple 60 dB

1. Show the time response and frequency response of this filter.
2. On the filter spectrum overlay the spectral lines corresponding to the DTMF tones.
3. Also plot the pole-zero Diagram of this design.



1. Design elliptic filters for the low band and the high band band-pass filters satisfies the following specifications.

Already at Low Band Sample Rate 4.3 kHz

Passband: Frequencies 690-950 Hz, Ripple 0.02 dB

Stopband: Transition Bandwidths < 250 Hz, Ripple 50 dB

Already at Hi-band Sample Rate 4.3 kHz

Passband: Frequencies 1200-1640 Hz, Ripple 0.02 dB

Stopband: Transition Bandwidths < 250 Hz, Ripple 50 dB

1. Show the time responses and frequency responses of the two designs.
2. On the filter spectrum overlay the spectral lines corresponding to the DTMF tones.
3. Also plot the pole-zero Diagram of the two designs.
4. Form 20,000 samples of a composite signal containing all 8-DTMF tones.
5. Pass the signal through the half band filter and reduce sample rate 1-to-2, *x2=x1(1:2:end).*
6. Then pass the down sampled signal through the two bandpass filters and reduce sample rate 1-to-4, *x4=x3(1:4:end).*
7. Show the spectra of the tones at the input and output sample rates of the two bandpass filters.
8. Due to the sample rate reduction, the tones in the high band have aliased to different center frequencies.
9. Determine the center frequencies of all 8 DTFM Tones at the reduced sample rate (fs/8).
10. Design the set of 8 elliptic bandpass filters centered on the aliased DTMF signal set. The tone filter order is 3. The two sided bandwidth of each filter is 10 Hz. The in band ripple is 0.02 dB and the required stop band attenuation is 60 dB.
11. Show the frequency response and impulse response of the 8-filters.
12. These should overlay the spectra of the aliased tones.

1. Generate a time series corresponding to the DTMF signal formed by depressing the three letters of your initials for 200 msec each separated by 200 msec gaps.

1. Show the time series and spectrum of this composite signal.

1. Pass the DTMF composite signal through your filter bank and show the time response of the filter bank; 4-subplots for row tones and 4-subplots for column tones.

Problem 2.

1. Repeat all the filter designs of problem 1 but this time use FIR filters designed by the “remez algorithm” instead of IIR filters.