Signal Processing
Lab 4

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In this Lab, we will encode and decode the signal of the telephone dialing using finite impulse response (FIR) filters.

1 Background: Telephone Touch Tone Dialing

Dual-tone multi-frequency (DTMF) signaling is used for telephone signaling over the line in the voice-frequency band to the call switching center. The version of DTMF used for telephone tone dialing is known by the trademarked term Touch-Tone. Telephone touch pads generate DTMF signals to dial a telephone. When any key is pressed, the tones of the corresponding column and row (in Tab. 1) are generated, hence dual tones. For example, pressing the 6 button generates the tones 770 Hz and 1447 Hz summed together.

Frequences (Hz)	1209	1336	1477
697	1	2	3
770	4	5	6
852	7	8	9
941	*	0	#

Table 1: DTMF Keypad Frequencies

There are several steps to decoding a DTMF signal:

1. Divide the signal into shorter time segments representing individual key presses.
2. Determine which two frequency components are present in each time segment.
3. Determine which button was pressed, 0-9, *, or #.

We can use a simple FIR filter bank to decode DTMF signals. The filter bank in Fig. 1 consists of filters which each pass only one of the DTMF frequencies.

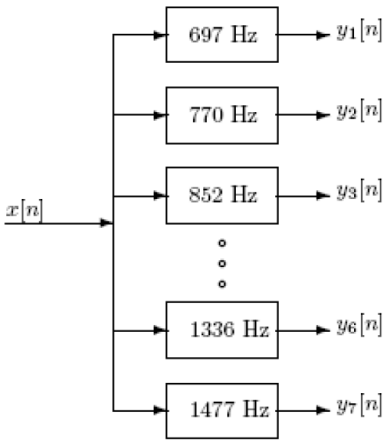

Figure 1: Bandpass Filter Bank for DTMF

2 DTMF Encoding

The signal of dual tones is defined as:

$$f(t) = 0.5\cos(2\pi f_1 t) + 0.5\cos(2\pi f_2 t) \tag{1}$$

Discretize the signal by samping at f_s and Complete the function, `dtmfDialer` (a skeleton is given to you in `dtmfDialer.m`), to implement a DTMF dialer defined in Tab. 1. Here are some conventions about this function:

1. The input to the function is a number which ranges between 0 and 11, with 0-9 corresponding to the digits, 10 the * key and 11 the # key.
2. The output should be a signal vector containing the DTMF tones, sampled at 8 kHz and with a duration of 0.5 second.

3 DTMF Decoding

3.1 Filter Design

A DTMF decoding system needs two pieces: a bandpass filter to isolate individual frequency components, and a detector to determine whether or not a given component is present. The detector must score each possibility and determine which frequencies are most likely present. In our lab, we don't consider the noise added in the signal since we aim to understand the basic functionality in the decoding system. However, it should be noted that in a practical system where noise and interference are present, the scoring process is a crucial part of the system design.

The filters that will be used in the filter bank (Fig. 1) are a simple type constructed with sinusoidal impulse responses. A simple bandpass filter is that the impulse response of the filter is simply a finite length cosine of the form:

$$h\,[n] = \frac{2}{L} cos(\frac{2\pi f_b n}{f_s}) \quad 0 \leq n < L \tag{2}$$

where L is the filter length, and f_s is the sample frequency.

1. What does the parameter f_b mean?
2. What characteristic does the parameter L control?
3. Generate a bandpass filter function, `h=bandpassFilter(L,fb,fs)`, where the meanings of L, fb and fs has been presented above and h is the bandpass filter's coefficient vector, i.e., the unit impulse response.
4. Generate two bandpass filters using `h=bandpassFilter(L,fb,fs)`, h697 and h1336, for the 697 Hz and 1336 Hz, both with L = 64 and fs =8000. Plot and compare the two filters.
5. Use the function `freqz` (given by `Octave`) to calculate the frequency response of digital filter h. Compare the magnitude responses of different filters and comment on the selectivity of the filters. And try to change the L and fb to see the change of the magnitude response of a filter. Compare it with your answers for questions (1) and (2).

3.2 Decoding Function

The DTMF decoding function, `dtmfdecoding` will determine which key/number was pressed based on an input DTMF signal by detecting the presence of frequencies in the input signal. The skeleton of this function is given in the file `dtmfdecoding.m`.

1. Complete the function `dtmfdecoding` to decide which key/number is present using the filter bank you have built.
2. Test your DTMF encoding-decoding system to verify that it does work.