C.7 LABORATORY: EVERYDAY SINUSOIDAL SIGNALS

This lab introduces two practical applications where sinusoidal signals are used to transmit information: a touch-tone dialer and amplitude modulation (AM) for radio. In both cases, FIR filters can be used to extract the information encoded in the waveforms.

C.7.1 Background

This lab has two parts. Part A investigates the generation and detection of the signals used to dial the telephone. Part B is concerned with modulation and demodulation of AM (amplitude modulation) waveforms such as those used in AM radio.

C.7.1.1 Background A: Telephone Touch Tone[15] Dialing Telephone touch pads generate *dual tone multifrequency* (DTMF) signals to dial a telephone. When any key is pressed, the tones of the corresponding column and row (in Fig. C.13) are generated, hence dual tone. As an example, pressing the **5** button generates the tones 770 Hz and 1336 Hz summed together.

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

Figure C.13 DTMF encoding table for touch tone dialing. When any key is pressed, the tones of the corresponding column and row are generated.

The frequencies in Fig. C.13 were chosen to avoid harmonics. No frequency is a multiple of another, the difference between any two frequencies does not equal any of the frequencies, and the sum of any two frequencies does not equal any of the frequencies.[16] This makes it easier to detect exactly which tones are present in the dial signal in the presence of line distortions.

[15] Touch Tone is a registered trademark of AT&T.

[16] More information can be found at: `http://www.shout.net/~wildixon`.

C.7.1.2 DTMF Decoding 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 **#**.

It is possible to decode DTMF signals using a simple FIR filter bank. The filter bank in Fig. C.14 consists of filters that each pass only one of the DTMF frequencies and whose inputs are the same DTMF signal.

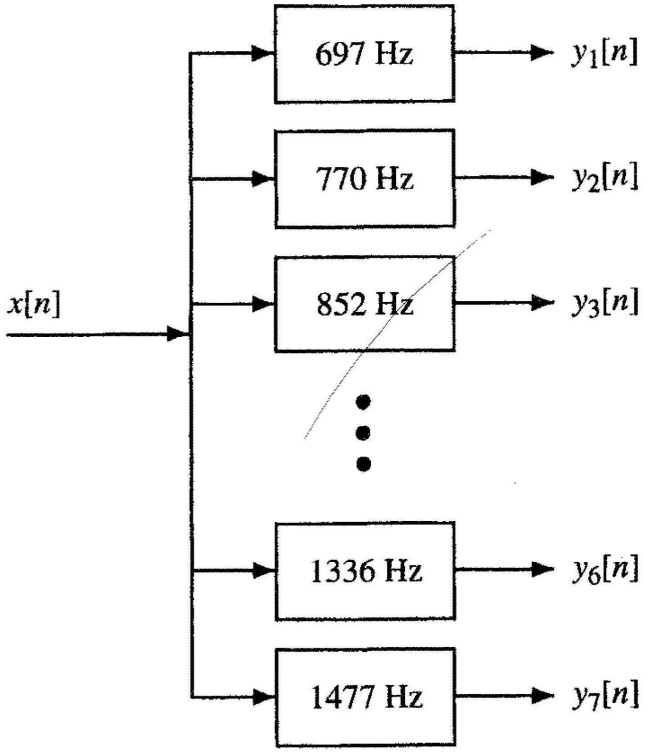

Figure C.14 Filter bank consisting of band-pass filters that pass frequencies corresponding to the seven DTMF component frequencies listed in Fig. C.13.

When the input to the filter bank is a DTMF signal, the outputs of two filters should be larger than the rest. The two corresponding frequencies must be detected in order to determine the DTMF code. A good measure of the output levels is the average power at the filter outputs. This is calculated by squaring the filter outputs and averaging over a short time interval. More discussion of the detection problem can be found in Section C.7.4.

C.7.1.3 Background B: Amplitude Modulation (AM) Amplitude modulation is often used to transmit a signal with low-frequency content using a high-frequency transmission channel. A common example is AM radio. In AM radio, a relatively low-frequency signal such as a speech signal (which has frequencies between 50 Hz and 4 kHz) is transmitted by radio waves at frequencies around 1 MHz.

Amplitude modulation is performed by multiplying a high-frequency signal (called the *carrier*) by a low-frequency *message* signal $m(t)$: