IST, Digital Signal Processing, Lab. #3 – Analysis
Pedro M. Q. Aguiar[1]
January, 2012

In this lab., we will deal with non-stationary signals, *i.e.*, signals whose spectral content varies with time. To that end, we will use common telephone dialing signals, produced according to the Dual Tone Multi-Frequency (DTMF) system. In DTMF, each phone key produces a sound that is the sum of two sinusoids, with frequencies specified in the following table.

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

1. Synthesis of a DTMF signal. Write a MatLab© function that receives a phone number and produces the corresponding DTMF audio signal, *e.g.*, `dtfmsignal=dtfmdial(number)`. Use a sampling frequency of 8KHz and insert a silence of duration 40ms between the consecutive digits.

2. Analysis of a DTMF signal. A common way to analyze a non-stationary signal $x[n]$ is through its localized Fourier Transform, also termed Short-Time Fourier Transform, or spectrogram, given by

$$X[n,k] = \sum_{m=0}^{L-1} x[n+m]w[m]e^{-j\frac{2\pi}{N}km}\,, \qquad 0 \le k \le N-1\,,$$

where $w[m]$ is a window.

a) Write a MatLab© function that receives a DTMF audio signal and produces the corresponding phone number, *e.g.*, `recovered_number=dtfmrecover(dtfmsignal)`. The code in the following lines illustrates, visually, the usage of the localized Fourier Transform in that task. Make sure you understand and justify the selection of the parameters involved, namely the values of L and N in the expression above.

```
>> [s,f,t]=spectrogram(dtfmsignal,300,[],[],8000);
>> mesh(t,f,abs(s));
```

b) Test your function `dtfmrecover` by attempting to recover the phone numbers from the signals produced by `dtfmdial`. Comment.

c) Load the sound file *touchtone* and use your function `dtfmrecover` to decode the number.

3. We now want to test the robustness of the analysis to noise corrupting the audio signal. To that end, generate noisy DTMF signals by adding Gaussian noise to the output of your function `dtfmdial`. Then, attempt to recover the phone numbers from the signal by using your function `dtfmrecover`. Perform several tests in order to be able to comment and discuss the influence of the noise magnitude, the time duration of each digit, and the parameters involved in the analysis. {`randn`}

[1]Parts of this document are based on a lab. assignment authored by João Sanches and Luís Caldas de Oliveira.