## LABORATORY SESSION AND BACKGROUND STUDY

## INTRODUCTION

Dual-tone multi-frequency (DTMF) signaling is a standard in telecommunication systems. In the DTMF scheme a telephone is equipped with a keypad as shown in Fig. 1.

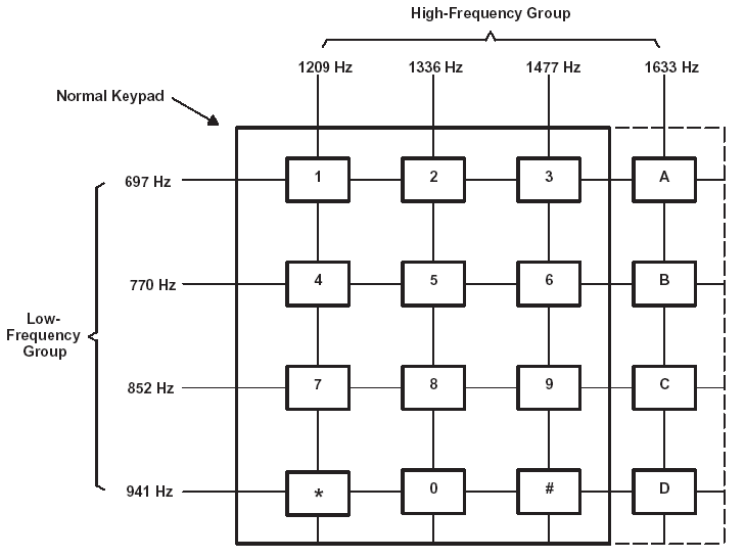


Fig. 1. DTMF Keypad

Each key represents the sum of a pair of tones. One tone is from the group between 1 KHz and 2 KHz, and the other one is from the group below 1 KHz. These frequencies are selected carefully so that the DTMF signal, which is the sum of the two tones, can be distinguished clearly as the signaling tone even in the presence of speech waveforms that might occupy the line. In order to reduce the risk of error, tones must be transmitted continuously for a minimum time of about 50ms, with an interdigit pause of a similar duration.

DTMF detection is used to detect DTMF signals in the presence of speech and dialing tone pulses. Besides being used to set up regular calls on a telephone line, DTMF detection is suitable for telephone control features.

## OBJECTIVES and INSTRUCTIONS

- The main objective of to use the DFT (efficiently implemented through the FFT algorithm) to carry out the DTMF detection, so for detecting two tones in a signaling signal x.

- The Background study questions must be answered before the Lab. session.

- The Lab. questions have to be answered during the lab sessions as a consequence from the obtained results.

- However, you only have to submit a technical paper. All theoretical and practical aspects learned during the elaboration of the background study and the lab. session must be reflected in the technical paper that you will submit via ATENEA.

## BACKGROUND STUDY

Background study question 1: Which is the mathematical expression corresponding to the DFT of a sinusoidal signal of period *N* and length *a·N* samples (where *a* is an integer number)?

Background study question 2: Plot the DFT of this sinusoidal signal.

## LABORATORY WORK

1. By means of the function '*load*' load the file XX.mat (each students group has been assigned a file) in Matlab's workspace. After loading XX.mat the signaling signal *x* will be available in the workspace for operating.

2. Plot the signal x.

   Lab. question 1: Which is the length of *x* in samples?

   Lab. question 2: What is the duration (in seconds) of the signaling signal? (consider that the sampling rate for obtaining *x* is $f_s = 8\ KHz$).

   You can listen to the sound of both tones:

   ```
   >> soundsc(x,fs)
   ```

3. Obtain the DFT of *x* (*X(k)*) and plot the modulus. (use the Matlab's *'fft'* function)

4. By analyzing the modulus of the DFT transform of *x*, answer the following questions:

   Lab. question 3: Find the DFT indexes (*k* values) for each one of the 4 DFT peaks. (consider the use of the Matlab's function '*max*').

   Lab. question 4: Obtain the digital frequencies corresponding to the two detected tones.

   Lab. question 5: Which are the analogue frequency values (in Hz) corresponding to the previously obtained digital frequencies?

   Lab. question 6: What key corresponds to this signaling signal *x* (see Fig. 1)?

   Lab. question 7: Which is the amplitude of the DFT peaks?

   Lab. question 8: Knowing the amplitude of the DFT peaks, calculate the amplitude of both tones used in the signaling signal *x*.