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CONTENTS

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DEVELOPMENT OF LOW COST SOUND LEVEL ANALYZER USING SCILAB FOR SIMPLE NOISE MEASUREMENT APPLICATIONS

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ABSTRACT

Sound is an impression of acoustic waves (disturbance/pressure fluctuations setup in a medium) and unpleasant, unwanted, disturbing sound is generally treated as Noise and is a highly subjective feeling. Noise is omni present, in other words Noise is becoming a progressively more ubiquitous. Regularly we hear from the people who return from the market about lot of noise pollution in the city. According to them vehicles and commercial units are responsible for escalating ambient noise pollution. During the functions like carnivals, wedding, birthday celebrations, social gathering etc., we can hear loud-speakers' Noise piercing the ordinary man's ear which gives rise to noise pollution. A great level of noise may cause strict strain on the auditory and nervous system. So, it is very much important to measure noise. For this purpose present study was carried out at various locations with Sound Level Meter to asses the day and night sound level in Rajkot City (Gujarat, India). Also, development of low cost Sound Level Analyser (SLM) was carried out, utilizing the sound card and microphone of PC and GUI programming features of the open source scientific computing language Scilab. Observation are compared with commercial sound level meter and found good matching. This paper aims at several essential concepts pertaining to noise measurement using hardware and software approach.

KEYWORDS

Measurement, Noise, Open Source, Scilab, Sound.

1. INTRODUCTION

Sound Pressure Level (SPL) is carried out when analyzing the acoustic properties of a building, environmental noise pollution, monitoring noise exposure of workers in industries, quality of audio equipment etc. It is insufficient to measure SPL as a function of RMS voltage, using a simple level meter or voltmeter, as the results obtained are not faithful. This is because noise contains energy spread over a wide range of frequencies and levels, and different sources of noise have different spectral content [3]. As a result, a filter which responds to the sound in a manner similar to the human auditory system should be developed. The filter should be capable of filtering out the frequencies below 22 Hz and above 22 kHz.

2. OBJECTIVE

The objective of present work is to design a low cost Sound Level Analyzer (SLM), utilizing the sound card and microphone of PC and GUI programming features of the open source scientific computing language Scilab. This leads to the development of an off-line A-weighted SLM, which estimates the Sound Pressure Level (SPL) of any mono wav sound file, recorded at any sampling rate or bit depth for the duration 1 min. at 'Slow' response rate.

The FFT algorithm is used to compute the N-point DFT for a time window, which depends on the sampling rate of a recorded file [1][2]. The resultant frequency spectrum is weighed using expression for A-Weighing Filter. The average energy of the signal in the frequency domain is estimated using Parseval's relation [1][2]. A simple front end graphical interface is designed for loading the wav file and display the plots of wav file, A-weighing filter response and dBA with time, in addition the SPL at distance of 0 through 60 sec, with intervals at 5 sec are also displayed.

3. SOUND LEVEL METER DESIGN

The primary consideration for designing the SLM is the utilization of Discrete Fourier Transform (DFT) to determine frequency spectrum[1] of a time windowed segment of a wav file and A-weighing Filter. To implement DFT we have used fft() function of scilab and created a dedicated function AweighingFilt() to emulate A-weighing filter.

4. IMPLEMENTATION OF DFT AND DETERMINING DFT LENGTH

It is a proven fact that the DFT can be used to approximate the DTFT, the N- point DFT equation is given by

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-\frac{j2\pi kn}{N}} \quad (1)$$

To find out the respective frequency of each DFT sample $X[k]$, we use the equation

$$\Delta f = \frac{f_s}{N} = \frac{1}{NT} \quad (2)$$

Where, f_s is the sampling frequency, *N* is the length of sequence and Δf is the frequency resolution.

To estimate DFT we have used Decimation-In-Time (DIT) Radix-2 FFT [1]. For Radix-2 FFT the input sequence must be a power of two i.e. $N = 2^m$, where *m* is a positive integer [2]. For a given sampling frequency f_s and period t [1 sec. for slow and 0.125 for fast rate], the minimum number of samples is given by

$$N_{min} = [f_s \Delta t] \quad (3)$$

Which may not be a power of two, so we find out next power of two greater than or equal to N_{min}, using the **nextpow2()** function

5. IMPLEMENTATION OF A-WEIGHING FILTER

As mentioned earlier, the A-weighing filter responds in a manner similar to the human ear. Although there are other weighing systems as well, but most widely used weighing scheme in most of the commercial SLMs is A-weighing. We can apply A-weighing directly to each FFT frequency bins without necessarily using 1/3-octave filters [1].

The implementation of A-weighing Filter can be done using the expression

$$\alpha_A(f) = \frac{(3.5041384 \times 10^{16}) f^8}{(20.598997^2 + f^2)^2 \times (107.65265^2 + f^2) \times (737.86223^2 + f^2) \times (12194.217^2 + f^2)^2} \quad (4)$$

The filter response is shown in fig. 1 It can be observed that the peak is obtained around 3000 Hz, there after it starts decreasing gradually till 22.05 kHz, which is imitation of human auditory system.

We then use frequencies [f_k] obtained by equation (2) for each FFT sample $X[k]$ to evaluate A-weighing filter coefficients in the above equation[1].

The A-weighted FFT samples are then described as

$$X_A[k] = \alpha_A(f_k) X[k], \text{for } f_k = k\Delta f \quad (5)$$

6. COMPUTATION OF THE SOUND PRESSURE LEVEL IN DBA

The Sound Pressure Level is at any given point is given by the expression given below

$$SPL\ (dBA) = 20\ log10 \left(\frac{P}{Pref}\right) \quad (6)$$

Where, P is the instantaneous sound pressure and $Pref$ is the reference pressure corresponding to the quietest perceivable sound or threshold of hearing i.e. $2\text{x}10^{-5}$ N/m2 (20 µ Pa).[4]

If we express in terms of energy then the above equation can be modified as

$$SPL\ (dBA) = 10\ log10 \left(\frac{E}{Eref}\right) \quad (7)$$

Where E instantaneous energy and $Eref$ is energy corresponding to the reference pressure.

The energy of audio signal can be calculated by finding out the sum of squared magnitudes of its samples. This condition holds true in the time domain, but as we have chosen the frequency domain for the processing either we have to find out inverse FFT and analyze the filtered signal in the time domain. Carrying out these steps would significantly increase the complexity of the software and also demand more computational resources. Hence, we find out energy of the signal in frequency domain using Parseval's relation [1] which is given by.

$$\varepsilon = \sum_{n=0}^{N-1} \|x[n]\|^2 = \frac{1}{N} \sum_{k=0}^{N-1} |X[k]|^2 \quad (8)$$

It is known that the DFT samples have complex-conjugate symmetry for real valued samples, and the same being the case with samples of wav file, we estimate the energy of the signal using the first $\frac{N}{2} + 1$ samples of the A-weighted FFT spectrum as depicted by the equation.

$$\varepsilon_x \approx \frac{2}{N} \sum_{k=0}^{\frac{N}{2}} \left|X_A[k]\right|^2, for\ x[n] \epsilon\ R \quad (9)$$

Using the symmetry property reduces the CPU consumption during process and also makes the algorithm less complex. As the Sound Level Analyzer supports various sample rates and response types, namely slow and fast, the average signal power should be used as expressed by the equation below:

$$\tilde{\varepsilon}_x \approx \frac{2}{N\Delta t} \sum_{k=0}^{N/2} |X_A[k]|^2, for\ x[n] \epsilon\ R \quad (10)$$

refer to the equation (7) to compute the dBA, we now have value of $\tilde{\varepsilon}_x$ with us, now we need to have value for $\tilde{\varepsilon}_{ref}$, since the input voltage for the reference pressure level is unknown and varies with different system. Now, substituting the values $\tilde{\varepsilon}_x$ and $\tilde{\varepsilon}_{ref}$ in the equation (7) we get

$$\textbf{SPL (dBA)} = 10 log_{10} \left(\frac{\tilde{\varepsilon}_x}{\tilde{\varepsilon}_{ref}}\right) = 10 log_{10}(\tilde{\varepsilon}_x) - 10 log_{10}(\tilde{\varepsilon}_{ref}) \quad (11)$$

As we know, that $Pref$ is a constant quantity, hence the corresponding energy $\tilde{\varepsilon}_{ref}$ will also be a constant, which states that $10 log_{10}(\varepsilon_{ref})$ is also a constant. As a result we can express above equation as

$$\textbf{SPL (dBA)} = 10 log_{10}(\tilde{\varepsilon}_x) + C \quad (12)$$

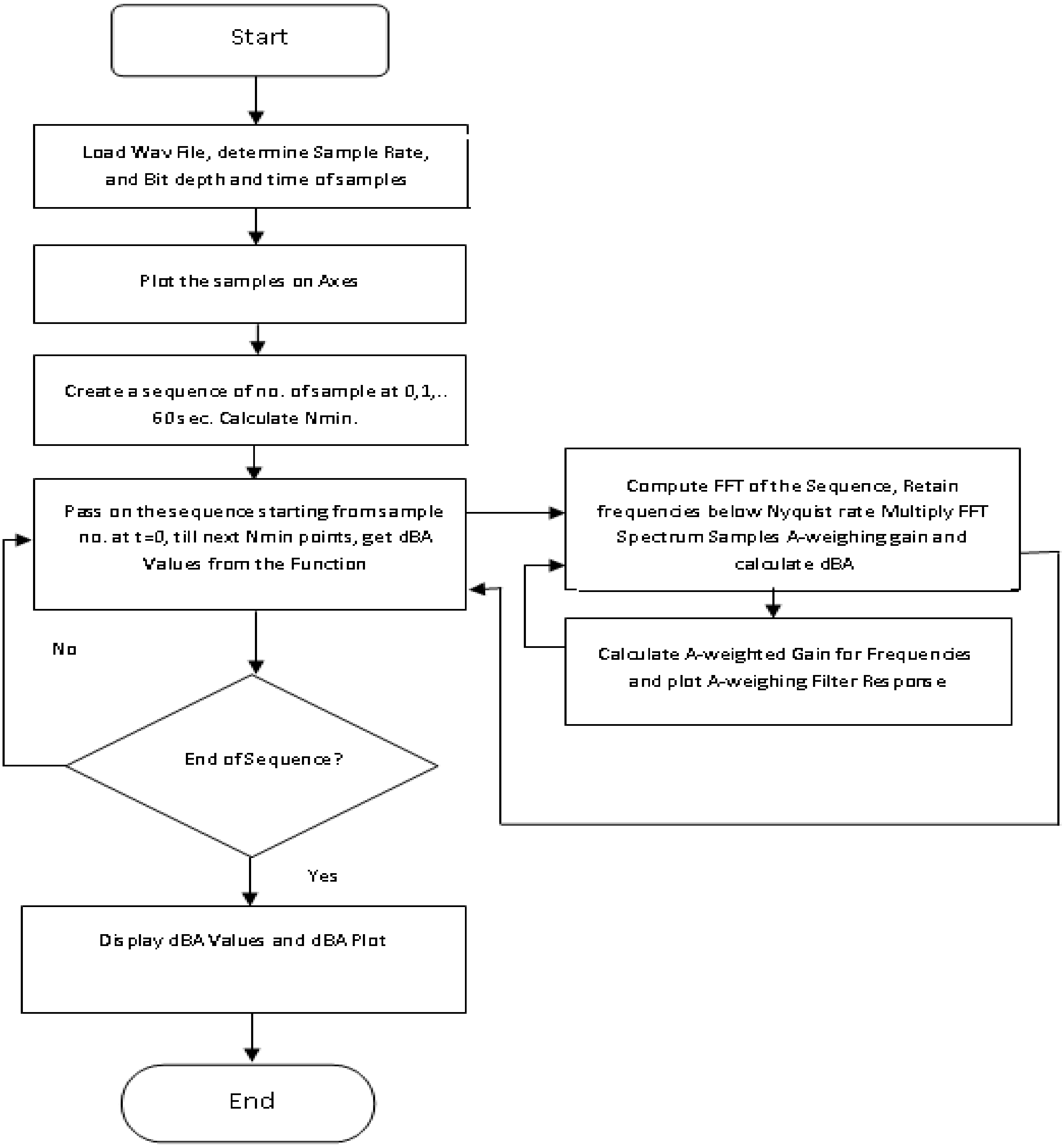
Where, C is a calibration constant, which can be found out experimentally.

7. SOFTWARE IMPLEMENTATION

For the software implementation of Sound Level Analyzer, we have used Scilab an open source scientific computation language, which can be downloaded free of cost from http://www.scilab.org. The front end of the software has been designed using "guibuilder" feature of Scilab to provide simple and Interactive Graphical User Interface.

The software consists of five major divisions namely (1) Front End User Interface (2) Loading, Plotting and acquiring information of wav file, (3) Determination of FFT window length and display of estimated data (4) Estimation of FFT spectrum, applying A-weighing to the FFT spectrum and computation of dBA and (5) A-weighing filter realisation.

FIG. 1: FLOW CHART OF FOR THE LOW COST SOUND LEVEL ANALYZER



7.1 FRONT END USER INTERFACE

The front end of software has been designed using 'guibuilder' feature of Scilab. The interface provides controls to load wav file, initiate processing and display of data on the window, set the Calibration constant C if required and also has the menu 'Info' to view the information about the loaded wav file.

FIG. 2: SCREEN SHOT OF SLA FRONT END INTERFACE

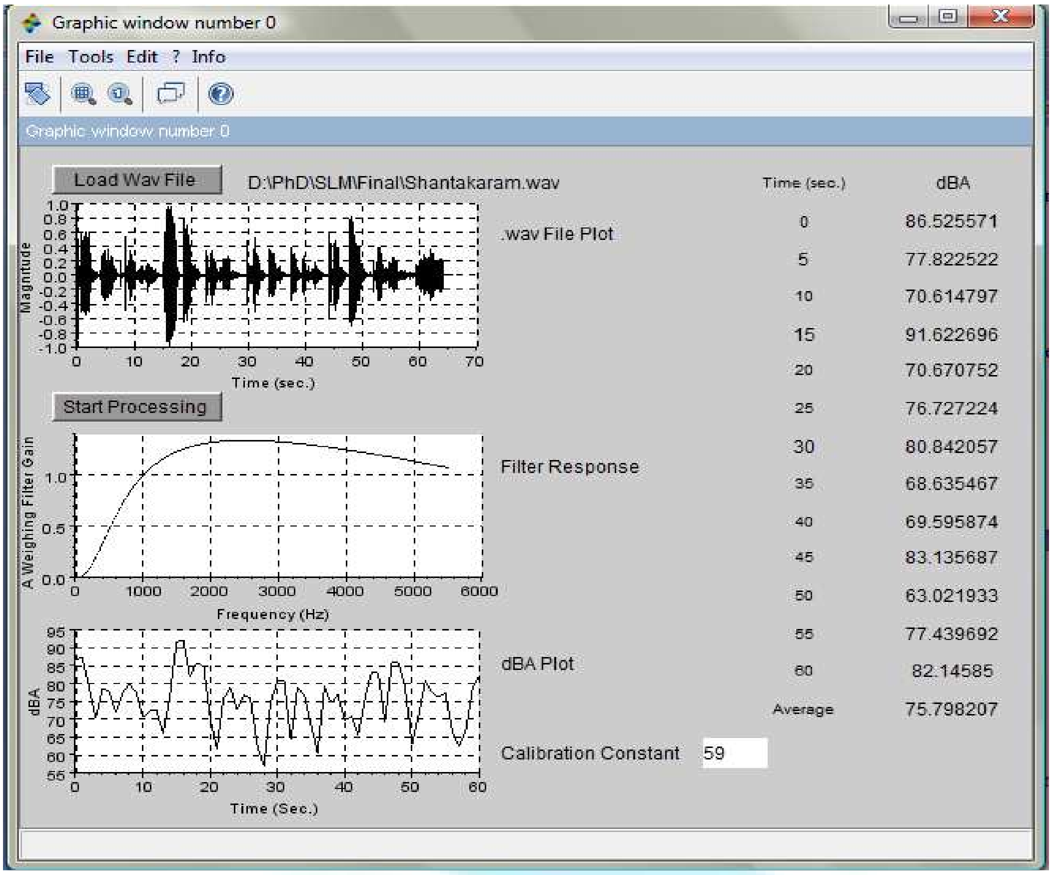
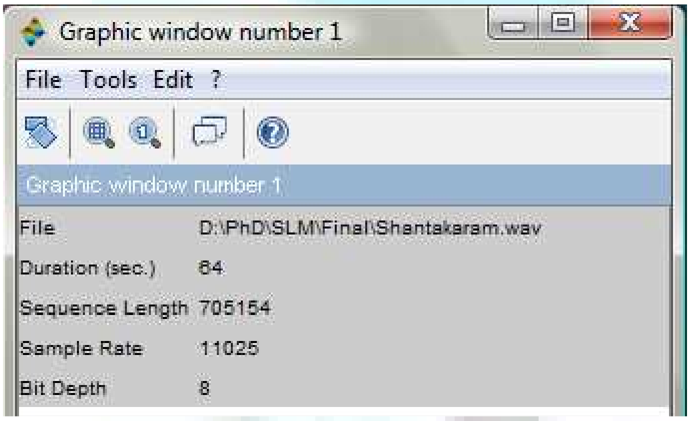


FIG. 3: SCREEN SHOT OF FILE INFORMATION WINDOW



7.2 LOADING, PLOTTING AND ACQUIRING INFORMATION OF WAV FILE

Once the user issues the command from the user interface the function written to load the file loads the specified wav file using the inbuilt function **wavread()** of Scilab. Various parameters like sample rate, bit depth, duration of file and length of sequence (No. of samples in file) are also determined in this section.

7.3 DETERMINATION OF FFT WINDOW LENGTH AND DISPLAY OF ESTIMATED DATA

Based on the sample rate the FFT window length greater than or equal to $N_{\min}$ is determined using **nextpow2()** function and the input sequence of that length is passed on to the function to perform the FFT estimation and end results are displayed on the window and on Axes2 based on the output obtained.

7.4 ESTIMATION OF FFT SPECTRUM, APPLYING A-WEIGHING TO THE FFT SPECTRUM AND COMPUTATION OF DBA

DFT estimation is carried out using fft() function to the input sequence passed from the previous function, as a result the FFT spectrum is obtained. The frequencies f_k are determined for samples of the FFT spectrum for the realistion of A-weighing filter. The A-weighing is applied to the samples of FFT spectrum and the instantaneous average energy is determined using the Parseval's relation and hence, the dBA is calculated.

7.5 A-WEIGHING FILTER REALISATION

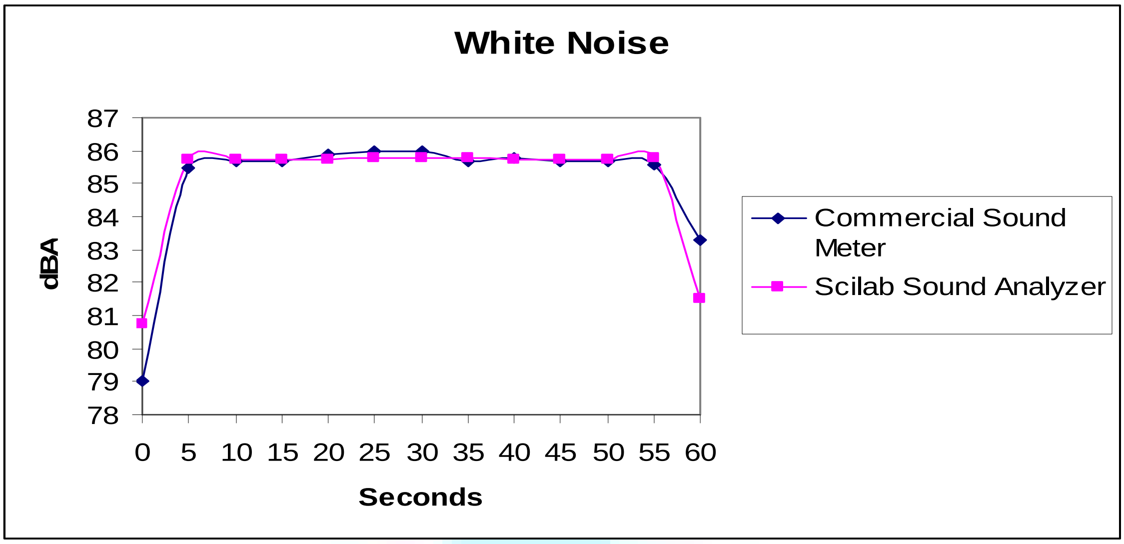
The A-weighing filter is realised using equation (4) and the coefficients are evaluated for the frequency of each sample of the FFT sample determined in the previous section. The A-weighing gain is then passed as the output of the function to the calling function.

8. COMPARISON OF SOUND LEVEL ANALYZER WITH COMMERCIALLY AVAILABLE SLM

To verify the reliability of the present Sound Level Analyzer we have compared it with a commercially available sound level meter. As the present work is best suited to work at slow response level (duration of 1 sec.) we have analysed various sounds by setting 'slow' response rate in the said commercial SLM.

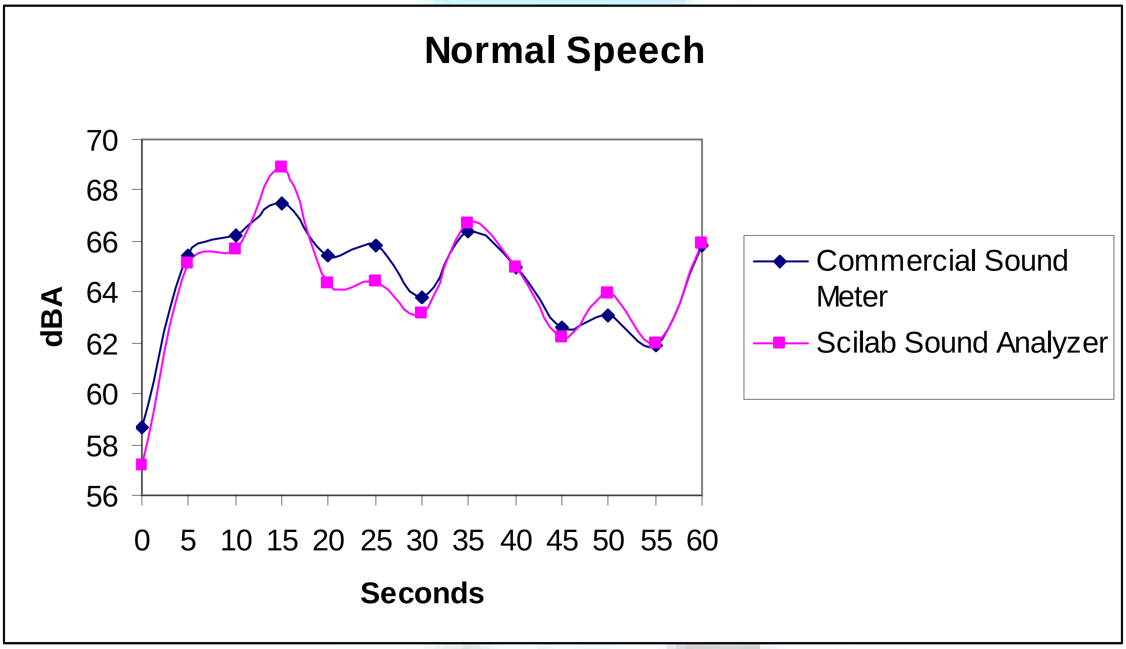
Firstly we have taken into consideration a wav file having white noise of the duration 1 min. The sound level meter was placed at a suitable distance from the speakers of PC, the wav file was played keeping the full sound volume of both the media player and the PC's speaker. The output observed using the SLM is noted at various time points such as 0, 5, 10, 15.... 60 seconds. It was observed that the output at 0 sec and 60 sec does not match, that is due to the lower sensitivity of the SLM (because of online processing). The readings of both SLM and SLA for white noise are shown in graph 1.

GRAPH 1: COMPARISON OF LOW COST SOUND LEVEL ANALYZER OUTPUT WITH COMMERCIAL SLM (FOR WHITE NOISE)



After comparing the SLM and LCSLA for white noise we compared them for normal speech signals. We placed the SLM close to the input microphone of PC and recorded the conversation using the sound recording software Wave Pad Editor. During the recording simultaneously the output of SLM was observed at the intervals of 0, 5, 10, ... 60 sec. At slow response level. The observations of both SLM and LCSLA are compared as given in graph 2.

GRAPH 2: COMPARISON OF LOW COST SOUND LEVEL ANALYZER OUTPUT WITH COMMERCIAL SLM (FOR NORMAL SPEECH SIGNAL)



9. CONCLUSION

The results obtained by comparing Low Cost Sound Level Analyzer with commercial Sound Level Meter show that the there is a close proximity between the observation of Sound Pressure Level monitored by SLM and the estimated SPL of LCSLA. There is very minor difference between the results obtained by both the objects under consideration due to different sensitivities and resolutions of the SLM and sound card of a PC and slightly due to minor position difference between both the input microphone of PC and SLM. Hence, it is found out that the LCSLA can be very handy in offline analysis of SPL.

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