"Removal of Heart Sound from Lung Sound using LabVIEW 8.6"

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Abstract- **It has been found that while analyzing Lung sound using stethoscope Heart sounds are intermixed with Lung sound. Heart sound interference with lung sound is one of major problem, as actually it affects the potential of lung sound which often effects the proper detection and diagnosis of disease. The aim of this proposed work is to implement a VI which can detect and separate out the HS segments from LS sound using Advanced Signal processing toolkit of LabVIEW 8.6. The method we will use is the multiresolution analysis of the wavelet approximation coefficients of the original signal to detect HS-included segments. Once the HS segments are identified, the method after detection removes them from the wavelet coefficients and estimates the created gaps by using TSA ARMA modeling and prediction.**

***Index Terms*—Virtual Instrument (VI), Multiresolution analysis (MRA), Time series analysis (TSA), Autoregressive Moving average (ARMA), Heart sound (HS), Lung sound (LS.**

I. INTRODUCTION

In today's world we have taken many steps to detect and diagnose the diseases occurring due to breathing disorders. In the last few decades, improvements in electronic recording and the development of computer-based methods have made quantitative studies of lung and tracheal sound signals possible as well as overcome many limitations of human ear subjective auscultation[4]. Modern digital processing techniques, along with advancements in computer analysis, have become an established research method for the investigation of respiratory sounds.

Auscultation is one of the most important non-invasive and simple diagnostic tools for detecting disorders in the respiratory tract like lung diseases [1]. It is defined as the act of listening for sounds within the body, mainly for ascertaining the condition of the lungs, heart and other organs. Diseases such as asthma, tuberculosis can be identified with this method through the analysis of lung and tracheal sounds. Research on the diagnosis of respiratory pulmonary conditions like bronchitis, sleep apnea, asthma (which are the terrible diseases) has established the utility of the stethoscope's acoustic signal in the common day to day practice. However, despite their effectiveness, these instruments only provide a limited and subjective perception of the respiratory sounds. The disadvantage of using stethoscopes and listening to the sounds using the human ear are a) their inability to provide an objective study of the respiratory sounds detected, b) their lack of sufficient sensitivity and (c) the existence of the imperfect system of nomenclature [3]. Since lung sounds have relatively low frequency and low intensity, it is essential to remove the noise and other interfering sounds (i.e., heart sounds) from the lung sounds prior to any diagnostic analysis.

Heart sounds overlap with lung sounds such that it hampers the potential of respiratory sound analysis in terms of diagnosis of respiratory illness. The features of lung sounds may be impure by heart sounds because lung and heart sounds overlap in terms of time domain and spectral content. This paper presents a method of lung sound analysis using the advanced signal processing tools of LabVIEW 8.6. The existing methods which are discussing here are not fully free from the artifacts of heart sounds. The software used in this method is having more flexibility; it removes the heart sounds and predicts the gaps successfully. It can also assist to general physicians to come up with more accurate and reliable diagnosis at early stages.

II. HEART SOUNDS AND LUNG

Lung sounds (LS) in breath sound recordings, however, are corrupted by intrusive quasi-periodic heart sounds (HS), which alter the temporal and spectral characteristics of the recording [6]. Features of lung sounds may be contaminated by heart sounds because lung and heart sounds overlap in terms of time domain and spectral content [7]. Heart sounds are clearly audible in lung sounds recorded on the anterior chest and may be heard to a lesser extent in lung sounds recorded over posterior lung lobes.

A. Lung Sounds

Breath sounds originate in the large airways where air velocity and turbulence induce vibrations in the airway walls. These vibrations are then transmitted through the lung tissue and thoracic wall to the surface where they may be heard readily with the aid of a stethoscope. Lung sounds are produced by vertical and turbulent flow within lung airways during inspiration and expiration of air. Lung sounds recorded on the chest wall represent not only generated sound in lung airways but also the effects of thoracic tissues and sound sensor characteristics on sound transmitted from the lungs to a data acquisition system. Lung sounds exhibit a Power Spectral Density that is broadband with power decreasing as frequency increases. The logarithm of amplitude and the logarithm of frequency are approximately linearly related in healthy subjects provided that the signals do not contain adventitious sounds increases and several mathematical relations between lung sounds and airflow have been proposed. Inspiratory and expiratory lung sounds differ in amplitude and frequency.

B. Heart Sounds

Heart sounds are produced by the flow of blood into and out of the heart and by the movement of structures involved in the control of this flow[10]. The first heart sound results when blood is pumped from the heart to the rest of the body, during the latter half of the cardiac cycle, and it is comprised of sounds resulting from the rise and release pressure within the left ventricle along with the increase in ascending aortic pressure. After blood leaves the ventricles, the simultaneous closing of the semi lunar valves, which connect the ventricles with the aorta and pulmonary arteries, causes the second heart sound. The electrocar- diogram (ECG) represents the depolarization and repolarisation of heart muscles during each cardiac cycle. Depolarization of ventricular muscles during ventricular contraction results in three signals known as the Q, R, and S-waves of the ECG [10]. The first heart sound immediately follows the QRS complex. In health, the last 30–40% of the interval between successive R-wave peaks contains a period that is void of first and second heart sounds. Characteristics of heart sound signals have been assessed in terms of both intensity and frequency. Though peak frequencies of heart sounds have been shown to be much lower than those of lung sounds, comparisons between lung sound recordings acquired over the anterior right upper lobe containing and excluding heart sounds show that PSD in both cases is maximal below 150 Hz.

III. VI IMPLEMENTATION

A. System Block Diagram

VI implementation is done using Lab VIEW 8.6 version. Advanced signal processing toolkit is used for this purpose. Here Wavelet analysis tools and Time series analysis tools are used for separating HS from LS recordings. The system block diagram is shown in fig1.

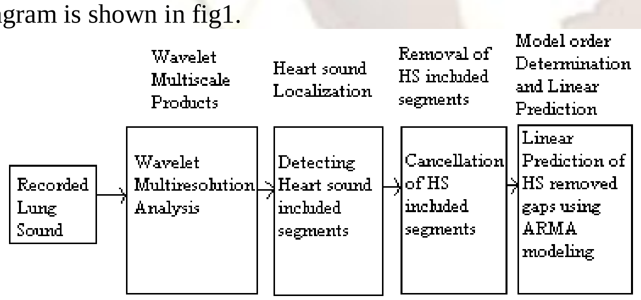


Fig.1. System Block diagram

The block diagram in fig1 shows that main idea of removing or separating heart sound from lung sound by applying the Discrete Wavelet Transform (DWT) to the original LS record and locate HS segments automatically and accurately using multiscale products, removing those segments from each level of the wavelet coefficients, estimate the removed segments by ARMA modeling of previous data segments. This is the method which is implemented using LABview8.6 which is discussed below in VI implementation.

B. Data Acquisition

Data used in this study, lung sounds, were acquired with a piezoelectric contact accelerometer (Siemens EMT25C) at the 3rd intercostals space anteriorly on the right upper lung lobe. Lung sounds were digitized at 10240 Hz and 12-bits per sample (National Instruments DAQ) with a custom written software in LabVIEW. Lund sound recordings are used as the input of this VI. These inputs are in .wav format which is read using Sound File Read Simple.VI.

C. Heart Sound Detection

The detection of heart sounds are done by the multiscale product of wavelet approximation coefficients. Multiresolution analysis.VI is used for this purpose, which is an express VI. Three scales were used in wavelet decomposition with the fifth order Symlet wavelet as the mother wavelet. The product of two adjacent decomposition bands presents very interesting properties. Signal and noise have totally different behavior in the wavelet domain.this behavior was analyzed using the concept of Lipschitz regularity. The multiplication of the DWT coefficients between the decomposition levels can lead to identification of singularities. In the case of HS detection, the multiscale product of the wavelet coefficients of the original LS record is used to identify the HS segments within the LS signal. Multiresolution Analysis VI decomposes the signal according to the level we specify and reconstructs the signal from the frequency bands we select. Fig. 2 is the arrangement for finding multiscale product of wavelet approximation coefficients Signals usually contain both low-frequency components and high-frequency components. Low-frequency components vary slowly with time and require fine frequency resolution but coarse time resolution. High frequency components vary quickly with time and require fine time resolution but coarse frequency resolution.

Multiresolution Analysis (MRA) method is used to analyze a signal that contains both low and high frequency components. Wavelet signal processing is naturally an MRA method because of the dilation process. The DWT is well-suited for multiresolution analysis. The DWT decomposes high-frequency components of a signal with fine time resolution but coarse frequency resolution and decomposes low-frequency components with fine frequency resolution but coarse time resolution. The central frequency and frequency bandwidth of the detail coefficients decrease by half when the decomposition level increases by one. For example, the central frequency and frequency bandwidth of *D2* are half that of *D1*. The approximation at certain resolution contains all of the information about the signal at any coarser resolutions. For example, the frequency band of *A*2 covers the frequency bands of *A*3 and *D*3. DWT-based multiresolution analysis helps to better understand a signal and is useful in feature extraction applications, such as peak detection and edge detection. Multiresolution analysis also removes unwanted components in the signal, such as noise and trend. The approximation at level 1 is the summation of the approximation and detail at level 2. The approximation at level 2 is the summation of the approximation and detail at level 3. As the level increases, lower frequency components will obtain, or large-scale approximation and detail, of the signal. Use the Multiresolution Analysis Express VI to decompose and reconstruct a signal at different levels and with different wavelet types [19].

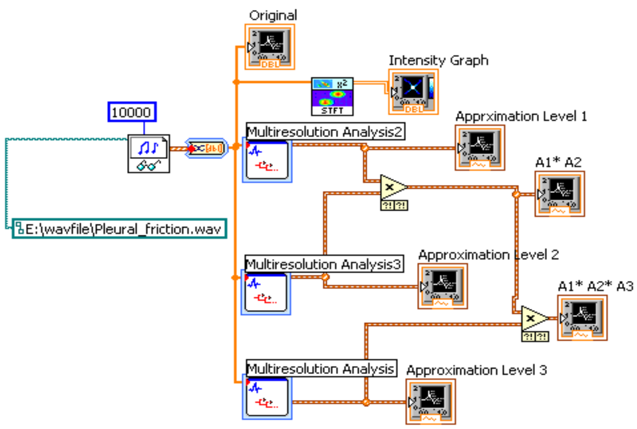


Fig.2. Block diagram of Heart sound detection

D. Heart Sound Cancellation

The DWT of the original LS record was obtained using the Symlet (order 5) wavelet, which is a compactly supported wavelet with least asymmetry and decomposing the signal into 3 levels. Then, the product of the wavelet coefficients was calculated[12]. The cancellation of heart sounds is done by applying a threshold such that,

$$A_i^{Th}(n) = \begin{cases} A_i(n)\, P_i(n) < Th\,, \\ 0 \quad \text{Otherwise} \end{cases}$$

$$\text{where} \quad \mathrm{Th} = (\mu \pm 5\,\sigma)$$

Th(n)are the original and threshold wavelet approximation coefficients at level *k*, respectively; and *Th* is the threshold value simply chosen to be above the mean plus or minus 5 times the standard deviation of the portions of original LS free of HS. To extract HS free portions of LS recording, we have to use an express VI named Extract Portion of Signal.

Fig. 3 is the block diagram for removing the HS included segments from the original LS including HS. The HS locations were detected accurately and removed from the DWT coefficients of the original LS record.

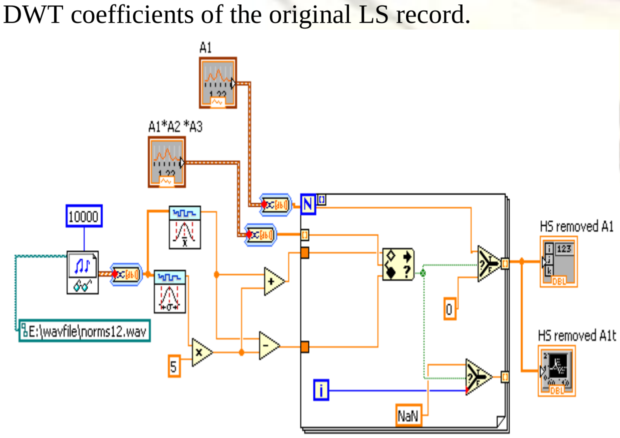


Fig.3.Block diagram for removal of HS.

Fig.4. shows the block diagram for locating the heart sound removed portions.

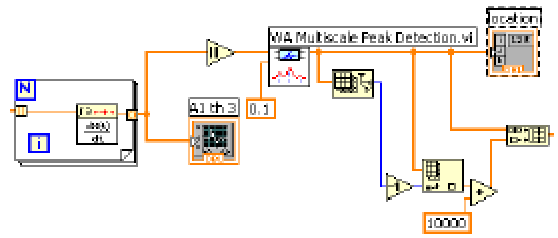


Fig 4.Localization of HS portions.

Next is the grouping of HS located nearby points. Fig. 4 shows the block diagram for this purpose. The locations are analyzed and find the portion of original LS to be replaced by the predicted series.

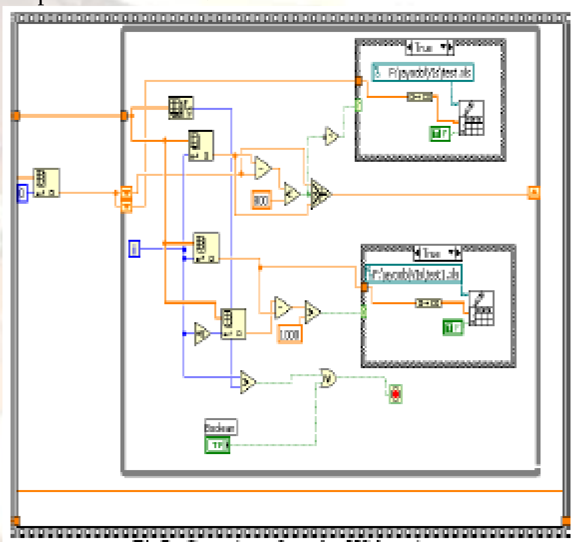


Fig.5. Grouping of nearby HS locations.

E. Modeling and Prediction

The next step was to estimate the removed data by linear prediction, using ARMA models. Here modeling of the LS input and then by using this model, we can predict the values of HS removed portions. TSA ARMA Modeling estimates the autoregressive-moving average (ARMA) model of an input univariate or multivariate (vector) time series according to the method we specify. We can use this polymorphic VI to estimate the ARMA model of waveform, array, vector waveform, and vector array signals. The data type wire to the **Xt** input determines the polymorphic instance to use. TSA ARMA Prediction predicts the values of an input univariate or multivariate (vector) time series based on the autoregressive-moving average (ARMA) model. We can use this polymorphic VI to perform ARMA prediction on waveform, array, vector waveform, and vector array signals. The data type wire to the **Xt** input determines the polymorphic instance to use.

Fig.6. is the block diagram for ARMA modeling and prediction.

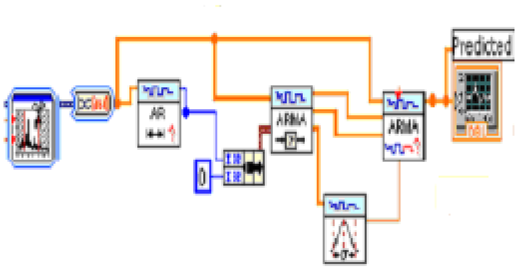


Fig.6.Block diagram of ARMA modeling and prediction.

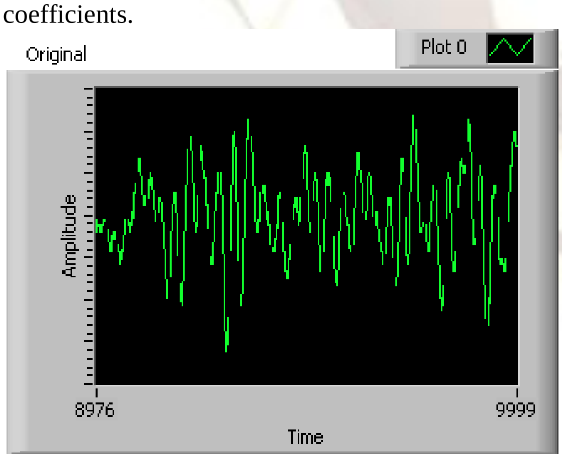
IV. SIMULATION RESULTS

A. Heart Sound Detection

The fig 7 shows the original LS and approximation coefficients of level 1 to level 3. Fig.8. is the product of the approximation coefficients of level 1, level 2 and level 3.

The detection of heart sounds are done by the multiscale product of wavelet approximation coefficients. Multiresolution analysis VI is used for this purpose, which is an express VI. Three scales were used in wavelet decomposition with the fifth-order Symlet wavelet as the mother wavelet. The product of two adjacent decomposition bands presents very interesting properties. Signal and noise have totally different behavior in the wavelet domain.This behavior was analyzed using the concept of Lipschitz regularity. The multiplication of the DWT coefficients between the decomposition levels can lead to identification of singularities. In the case of HS detection, the multiscale product of the wavelet coefficients of the original LS record is used to identify the HS segments within the LS signal.

Multiresolution Analysis VI decomposes the signal according to the level we specify and reconstructs the signal from the frequency bands we select. Fig. 8 is the arrangement for finding multiscale product of wavelet approximation coefficients.



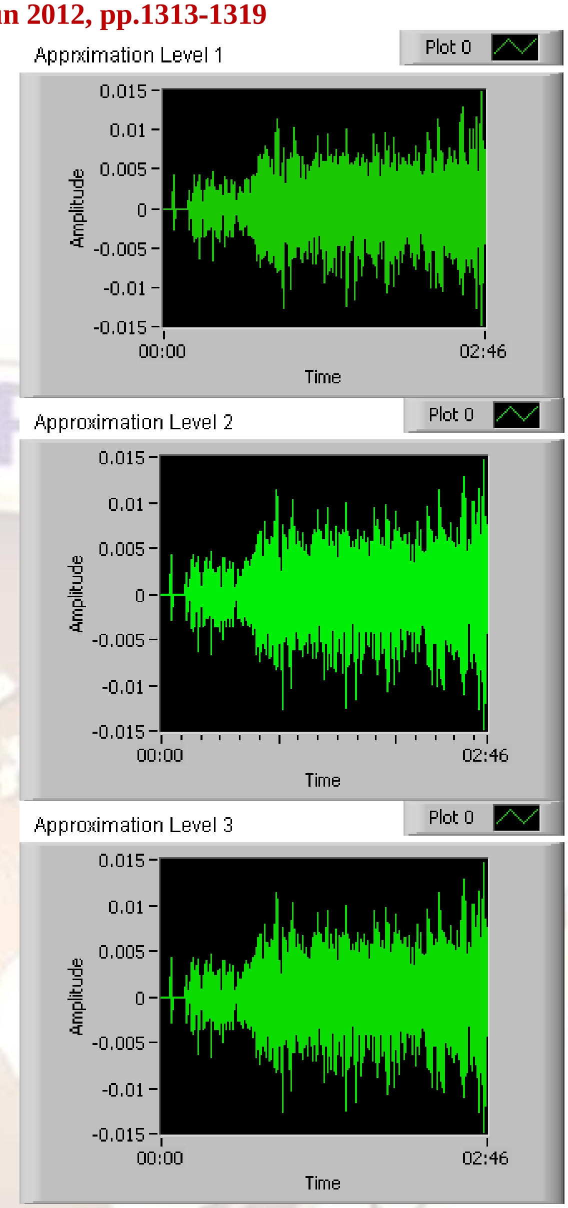


Fig.7. Original LS and the approximation coefficients at levels 1, 2
and 3 respectively.

Fig.7. is the product of the approximation coefficients of level 1, level 2 and level 3.

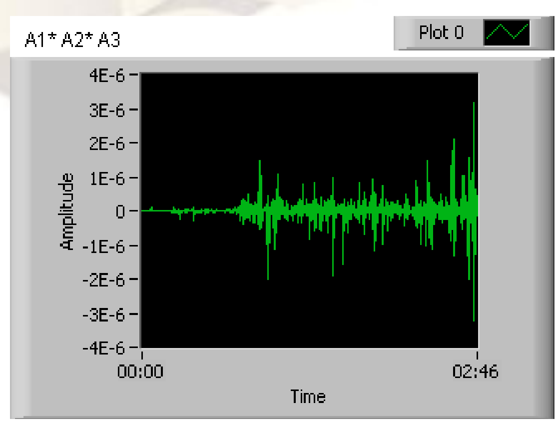


Fig.8. Multiscale product of approximation coefficients of 1 to 3 levels

B. Heart Sound Cancellation

HS affected portions of approximation coefficient 1 is removed and it is made as zero which is given in fig. 9.

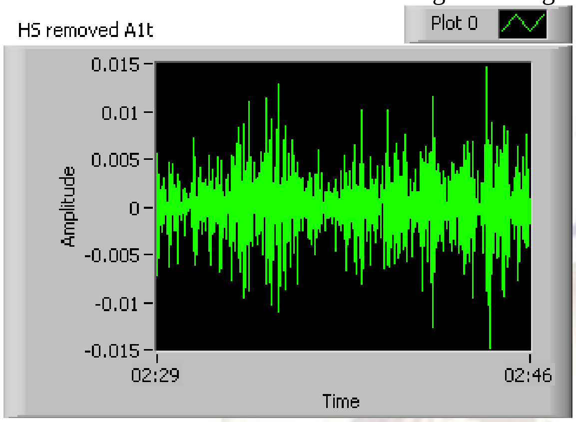


Fig.9. HS cancelled LS

C. Modeling and Prediction

Fig.10. (bottom) shows the reconstructed LS signal of original LS and signal shown in Fig.12. (top), after HS removal. As it can be seen, all HS segments were removed successfully and the main lung sound components were left intact.

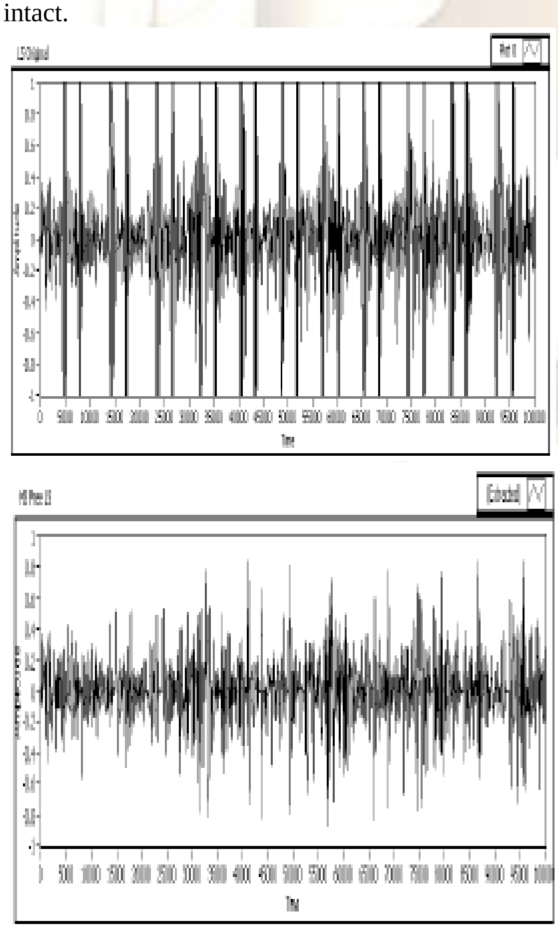


Fig.10. Original LS(top) and HS separated LS(bottom)

Fig.11. is the expanded views Fig. 10..

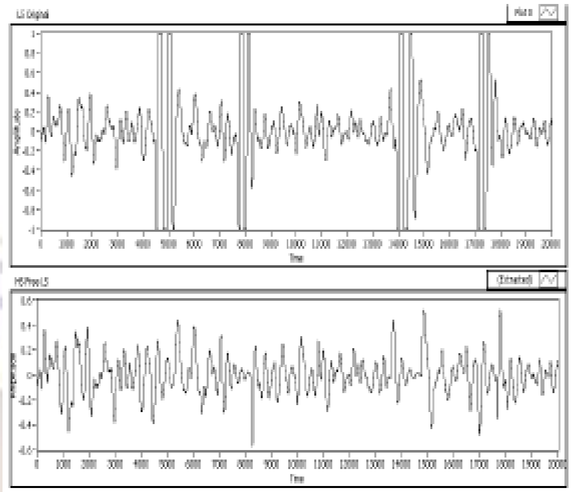


Fig.11. Original LS (top) and HS separated LS (bottom) for 20000
samples

D. Validation of Output

The validation of the result is done by STFT Spectrogram and Power Spectral Density (PSD) analysis of original LS including HS and HS separated LS which are given in Fig.12 and Fig.13 respectively.

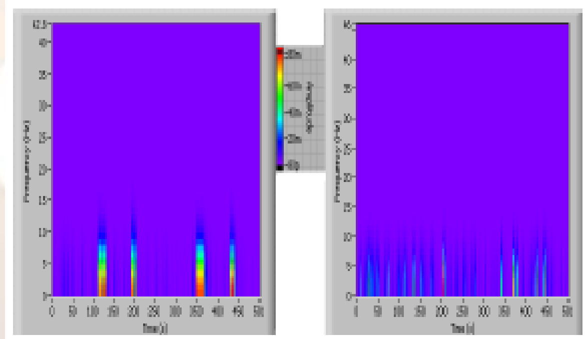


Fig.12. STFT spectrogram of original LS including HS (left) and HS
separated LS (right)

The results of PSD analysis of the original and the reconstructed signals are shown in Fig. 16.

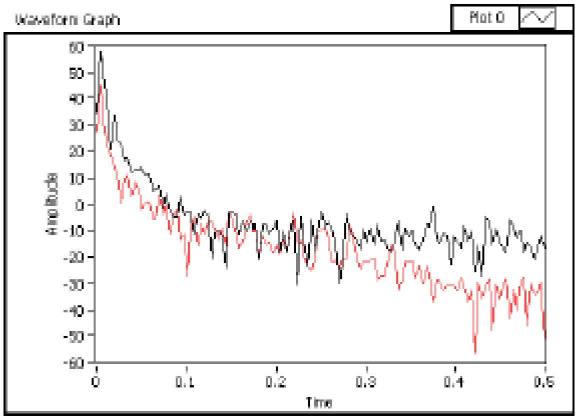


Fig.13. PSD of original LS including HS (black curve) and HS separated LS (red curve).

V. CONCLUSION

Lung sound analysis for detecting diseases is difficult when lung sound gets overlapped with heart sound because the heart and lung sound signals overlap in the time and frequency domains, removing HS interference from respiratory sound recordings is a big challenging and difficult task.

Computerized respiratory sound analysis can quantify changes in lung sounds, de-noise the signals of interest from any artifacts and nosiness, store records of the measurements made, and produce graphical representations of characteristic features of the respiratory sounds to help with the diagnosis and treatment of patients suffering from various lung diseases.

This method is one of the efficient computerized method to detect and eliminate the HS segments From LS. It can help respiratory sound researchers to bring about improvements to monitoring and diagnosis of respiratory disease. The potential usefulness of any method for removing heart sounds from lung sounds works on its ability to perform in a clinical setting. Manual inspection by visual means of the reconstructed signals confirmed that lung sounds were the dominant sounds with no perceptible HS in the background. Also, the proposed technique in this paper is far more efficient than other techniques for HS cancellation in terms of computational load and speed. This paper presents a best method for heart sound cancellation from lung sound records using LabVIEW. Once the HS segments are identified, the method removes them from the wavelet coefficients at every level and estimates the created gaps by ARMA model. The results were promising in HS removal from LS without hampering the main components of LS. This method did not add any noticeable clicks or artifacts in the reconstructed signal. This method can also be expanded to work on real time basis.

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