

The Feasibility Study of Mobile-to-mobile Communication for Auscultation of Heart Sound and Lung Sound

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Abstract—This study presented to insert a small-scaled microphone of the ear-set of a smart mobile (Galaxy Beam, GT-I8530, SamsungTM) into an eartip of the stethoscope, the sound can be transmitted by the mobile when it dialed to another phone or mobile. In this study, we employed another smart phone (Windows Phone 8X, hTC TM) to be the receiver. The results were showed by time sequence signals as well as spectrograms which demonstrated the components of frequencies of the sounds. Surprisingly, the recorded sounds of subject's mobile were much noisier than those of doctors', because of the very advanced technology of mobile communication which included the auto gain control (AGC), digital filter, noise cancellation and amplifier technologies to improve the quality of communication. We believe that the mobile-to-mobile communication is feasible to be the mean of distant auscultation. The perspective on the filtering modes, we got the conclusions of the distant auscultation, i.e. lung sound is better than heart sound.

Keywords—acoustic signal, lung sound, heart sound, mobile, cellular phone, smart phone, distant healthcare.

I. INTRODUCTION

Heart sounds (normal or pathological) are occurred by turbulent blood flow with the sound of the closing valves. Laminar flow is silent, but turbulent flow makes a sound. Cardiovascular diseases cause from medical conditions related to the heart or vascular system. Generally, there are two familiar types of cardiovascular disease which are

hypertension and atherosclerosis [1].

Respiratory sounds occur both of the durations of inspiration and expiration. The reasons of the respiration sounds occur as the air moves in and out of the chest when a person breathes normally. Therefore, the auscultation of normal breathing sounds and abnormal or adventitious sounds can be detected by the stethoscopes [2].

In the ordinary therapeutic and diagnosis procedures, the patents of heart or lung diseases, such as wheeze, hypertension, or heartache, go to the clinics or hospitals for medical doctors' auscultations periodically. However, the discomfort or absence of the patents occur unpredictably. A distant auscultation and recording system which functions as an auscultator or a listener is good at the diagnosis of the medical doctors to get the fresh information from the patents in their daily life. This enhances the lost information of the regular auscultations when the patents go to the hospital or clinics, and increase the precision or convenience of the medical doctors' diagnosis. The telephone has been popular for the communication of the human beings for 150 years [3]. In the advanced countries, the users of the traditional telephones are growing, and the mobile subscribers are much increasing than the traditional telephone does. From the point of feasibility view, the messages from mobiles are much convenient than other medium, such as magazines, radio, and so on. Most existing call centers cannot support video with their current technology, creating a powerful new reason for enterprises to consider call center equipment upgrade and replacement options. The interactive voice response (IVR) is

a well-known application of telecommunication [4].

The IVR presented the convenience of the telemedicine in patients and medical stuffs interactivities. It is a voice service for clients. In general, the database systems are usually operating in the switch system to record the data of the services. Sometimes, the voice is not sufficient for the reasons of security, convenience, and entertainment. Therefore, the concept of video server was introduced. The interactive voice & video response (IVVR) improved the voice-only services, and made the interface much friendly [5].

Contemporary smart phones, such as the Galaxy Note IV (Samsung), New One (hTC), and iPhone 6 (Apple), are widely used because numerous new applications (APPS) are available for the new generation of smart phones. Based on new wireless communication technologies, which include Bluetooth® technology, the 3G and 4G mobile communication systems, and modern electronic stethoscopes, we developed a mobile-based real-time stethoscope (MBRS) that can be applied in distant health care to improve the convenience of performing real-time auscultation on patients [6].

II. METHOD

A. Mobile-to-Mobile

The picture of smart phones was presented in Fig. 1. We inserted a small-scale microphone attached to the ear set of a smart mobile (Galaxy Beam, GT-I8530, Samsung™) into the ear tip of a stethoscope to transmit sound through the mobile when it dials and connects to another phone or mobile. We employed another smart phone (Windows Phone 8X, hTC™) to serve as the receiver. If the receiver is embedded with a real-time recorder, such as a circuit or computer software, then the detected sounds can be stored for subsequent analysis [7,8].

Figure 2 shows a block diagram of the MBRS. The input is the electronic stethoscope (3M™ Littmann® Model 3200) [9]. The stethoscope was designed using technologies for ambient noise reduction, frictional noise dampening, electronic amplification, and Bluetooth® data transfer, as well as an all-new user interface.

The Galaxy Beam was the biggest surprise from Samsung in the mobile phone category. It is a normal 1 GHz Android smart phone with a normal 4 inch display. What makes this model different is the built in mini projector. Everything seen on the display can be projected on a surface between 2 meter and infinite. At least as far away as the light goes. The camera can be used as a "reader" and project anything it captures to a nearby wall. The 2000 mAh battery will last for up to three hours when the projector is used.

The hTC Windows Phone 8X has a dedicated amp built right into the phone, so it pumps more power to your headphones than ever. Plus, Beats Audio is coming to

Windows phones for the first time ever. Take that combination and transform your listening pleasure with deeper bass, crisper vocals and detailed high notes for music, games, movies and videos.

B. Spectrogram

The element at the time τ in a spectrogram is defined as [10]:

$$|X_{\tau}(j\omega)|^2 = \left| \int_{-\infty}^{\infty} x(t)\phi_{\tau,\omega}(t)dt \right|^2 \quad (3)$$

where $x(t)$ is the signal in the time domain, $\phi_{\tau,\omega}(t)$ is the complex basis function, and $|X_{\tau}(j\omega)|^2$ is the power distribution in the frequency domain at the time τ . This form of the Fourier transform, also known as the short-time Fourier transform (STFT), has numerous applications in speech, sonar, and radar processing. The spectrogram of a sequence is the magnitude of the time-dependent Fourier transform versus time.

Many researchers of the heart and lung sound analysis employed the technology of spectrogram analysis to explore the characteristics of the heart and lung sounds, because the spectrogram presents the power densities in both of time and frequency domains [11,12]. It clearly shows the characteristics of the signals in 3 dimensional presentations.



Fig. 1. The smart phones: Galaxy Beam, GT-I8530, Samsung™ as transmitter, and Windows Phone 8X, hTC™ as receiver.

C. 3M™ Littmann® Electronic Stethoscope Model 3200

The Model 3200's combination of Ambient Noise Reduction technology, frictional noise dampening materials, electronic amplification (conventional bell / diaphragm modes plus an extended range mode), Bluetooth® data transfer, and an all-new user interface takes you to the next level of performance and ease of use.

This electronic stethoscope allows the user to select

between three different digital frequency filters to better emphasize the specific patient sounds of interest. (1) The Bell mode amplifies sounds from 20 - 1000Hz, but emphasizes lower frequency sounds between 20 - 200Hz. (2) The Diaphragm mode amplifies sounds from 20 - 2000Hz, but

emphasizes the sounds between 100 - 500Hz. (3) The Extended Range mode amplifies sounds from 20 - 2000Hz similar to the Diaphragm Mode, but provides more low frequency response between 50 - 500Hz.

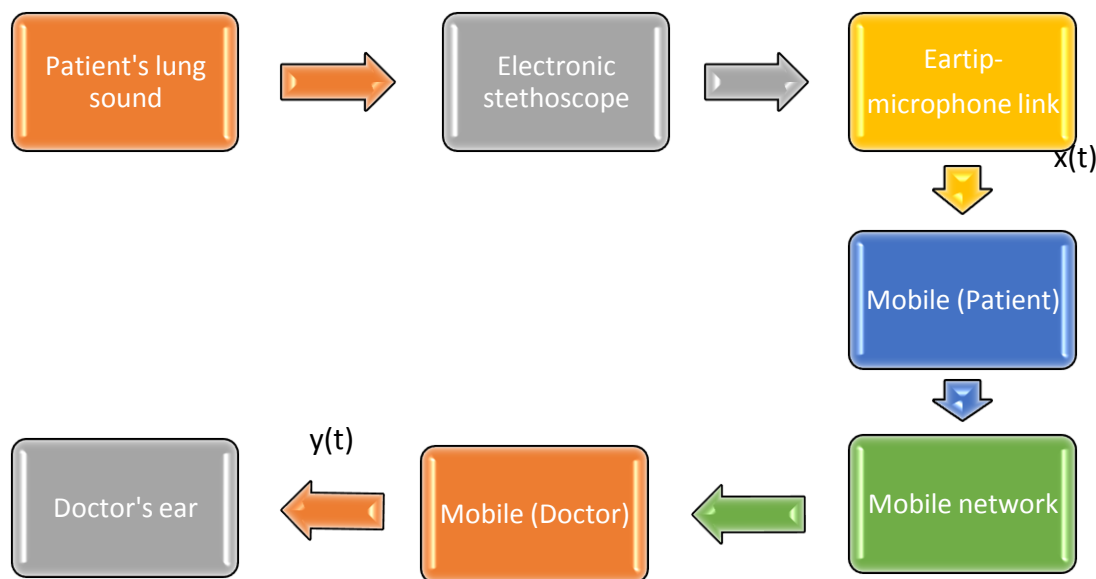


Fig. 2. The functional block diagram of testing the reliability of the real-time distant electronic stethoscope.

III.RESULTS

Figure. 3. Heart sound in the diaphragm filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile. (near_2102_diaph_lung.wav, far_2102_diaph_lung.wav)
Comments:

Figure. 4. Heart sound in the extend filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile. (near_2104_ext_lung.wav, far_2104_ext_lung.wav)

Figure. 5. Heart sound in the bell filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile. (near_2106_bell_lung.wav, far_2106_bell_lung.wav)

Figure. 6. Lung sound in the diaphragm filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.
Comments:

Figure. 7. Lung sound in the extend filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

Figure. 8. Lung sound in the bell filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

The senior medical doctor gave the comments of the recorded sounds. He said that "The qualities of the lung

sounds were better than the heart sounds. Some distortions of the lower frequency components in the heart sounds did not be good enough. Generally, the quality of lung sounds are good".

IV.DISCUSSION

Surprisingly, the recorded sounds of subject's mobile were much noisier than those of doctors', because of the very advanced technology of mobile communication which included the auto gain control (AGC), digital filter, noise cancellation and amplifier technologies to improve the quality of communication. It is true that the heart and lung sounds can be delivered to the doctor's mobile phone with the sounds of very high quality, even though the original transmitted sounds were noisy in a common environment.

Some distortions of the lower frequency components in the heart sounds did not be good enough, because of the lower cutoff frequency is about 50 Hz [Extended Adaptive Multi-Rate-Wideband]".An excellent stethoscope can aid the doctors to detect the problems of hearts or air ways of the patients. However, the abnormal sounds are not always occur. When the patients go to hospital, their chief complains were described by the histories of their daily-life. This system of this study supports the possibility of the real-time diagnosis to enhance the precision of the auscultation.

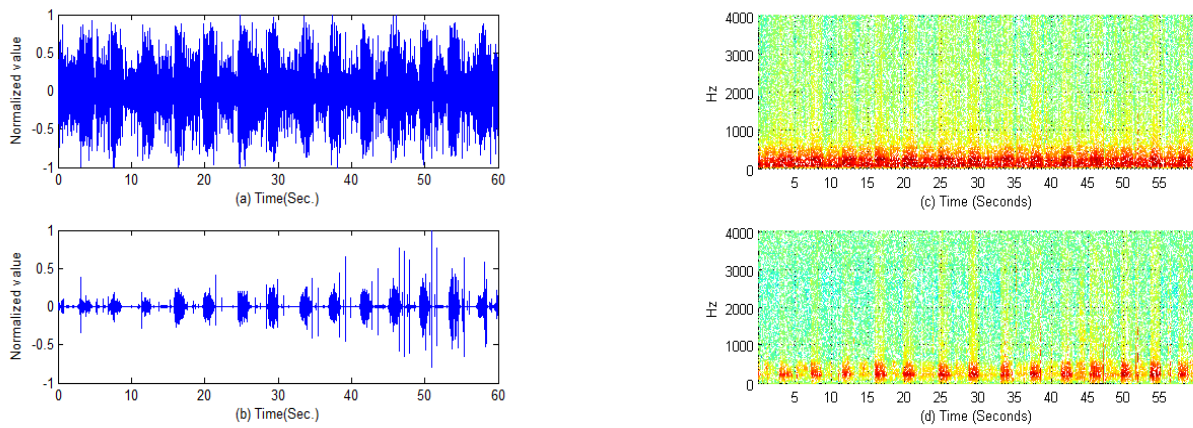


Fig. 3. Heart sound in the diaphragm filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

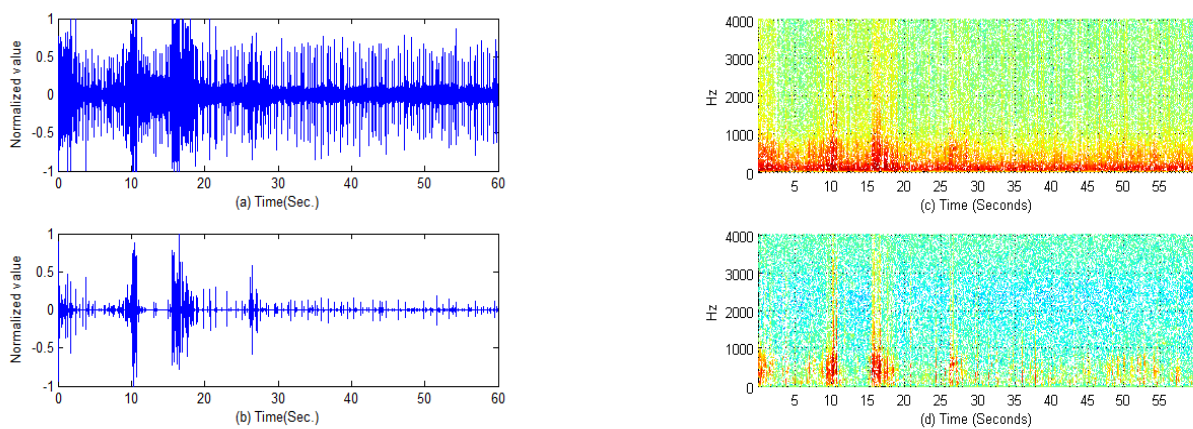


Fig. 4. Heart sound in the extend filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

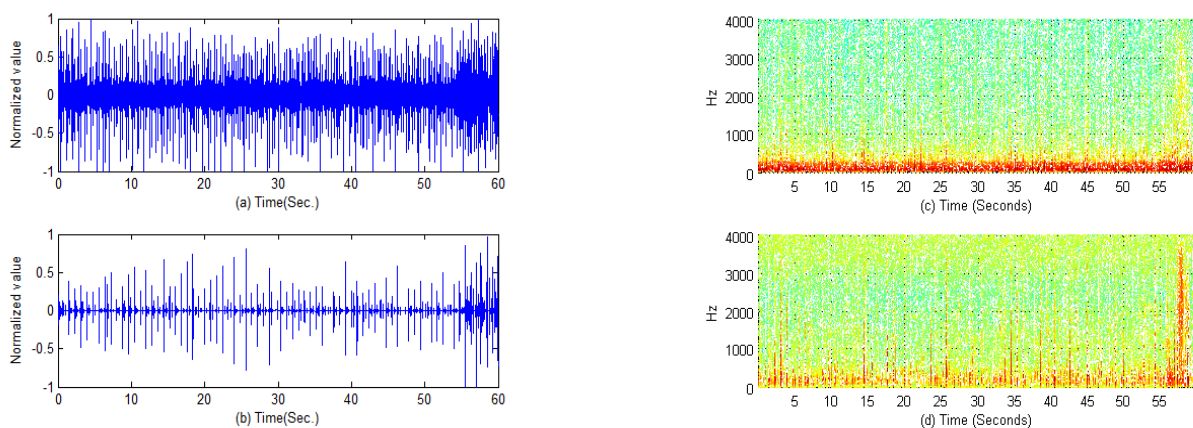


Fig. 5. Heart sound in the bell filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

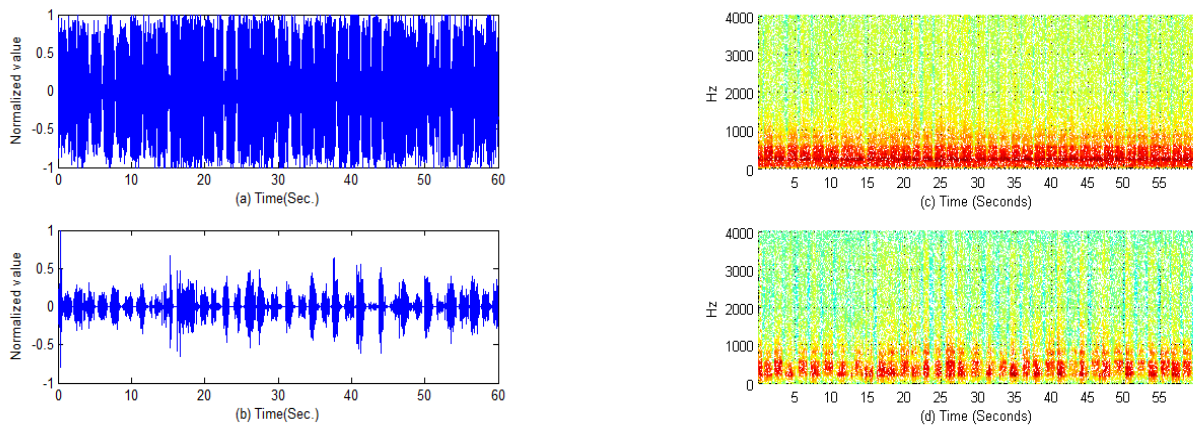


Fig. 6. Lung sound in the diaphragm filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

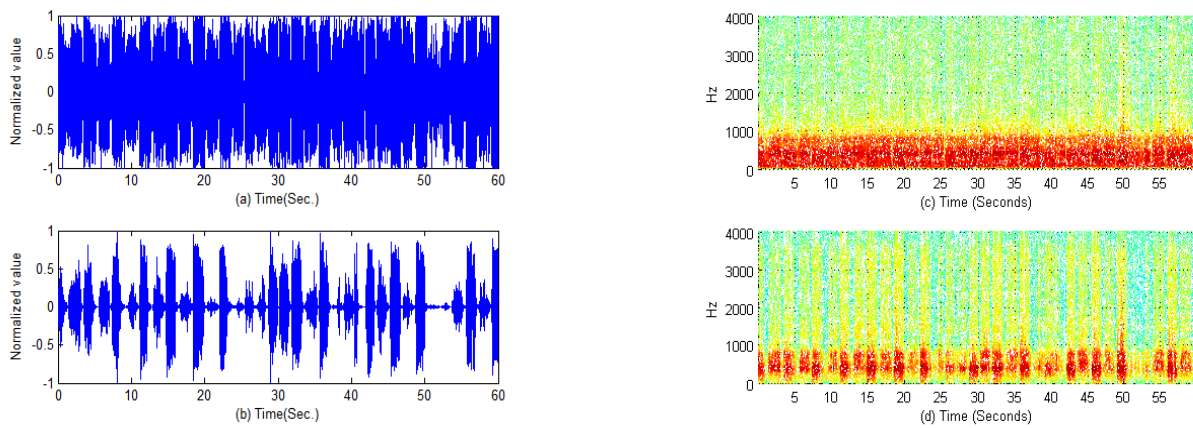


Fig. 7. Lung sound in the extend filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

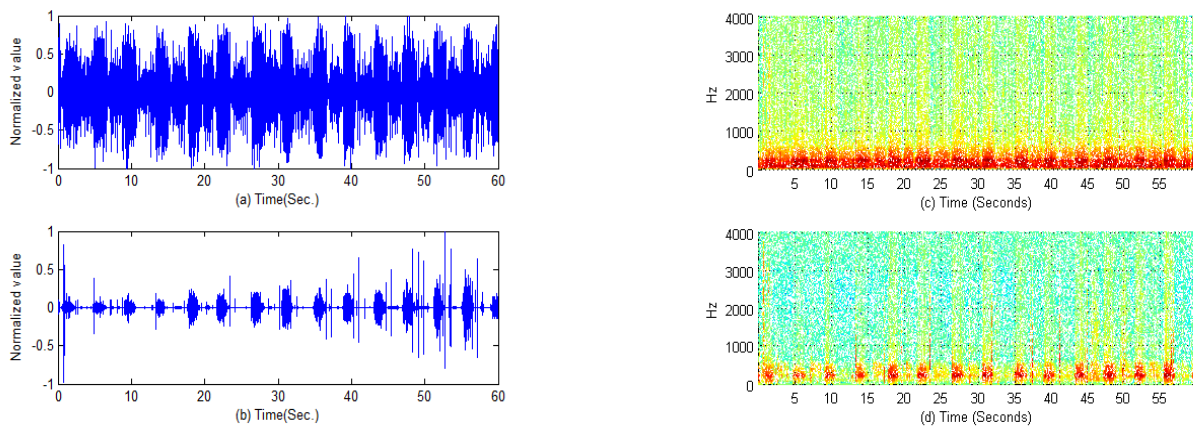


Fig. 8. Lung sound in the bell filter mode:(a) subject's mobile, (b) doctor's mobile, (c) spectrogram of subject's mobile, and (d) of doctor's mobile.

V. CONCLUSION

We believe that the mobile-to-mobile communication is feasible to be the mean of distant auscultation. This electronic stethoscope is a very good tool for the amplification of the heart and lung sounds. The perspective on the filtering modes, we got the conclusions of the distant auscultation, i.e. lung sound is better than heart sound. Based on the benefits of the modern communication systems, we can cancel the noises of the transmitting mobile and get a clear sound in the receptor mobile. The further tele-communication applications of sounds were encouraged by the surprising results of this study.

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